2022

AF&PA
RECOVERY BOILER PROGRAM
ANNUAL CONFERENCE

FEBRUARY 2, 2022
ATLANTA, GEORGIA

American Forest & Paper Association
Recovery Boiler Committee

American Forest & Paper Association

AF&PA RECOVERY BOILER PROGRAM
2022 ANNUAL CONFERENCE
ATLANTA, GEORGIA

Atlanta Airport Marriott
February 2, 2022
Florida/Tennessee/Alabama/Georgia Rooms

AGENDA

Wednesday, February 2, 2022

7:00 am	Registration & Continental Breakfast - Wayne Grilliot
8:00 am	General Assembly – Review AF&PA Antitrust Policy & Chairman's Report - Frank Navojosky – International Paper
8:05 am	Operation & Maintenance Subcommittee Report - Wes Hill – Georgia-Pacific
8:15 am	Research & Development Subcommittee Report - Jeff Wagoner – International Paper
8:25 am	Recovery Boiler Corrosion Environments - Honghi Tran – University of Toronto
9:05 am	NDT: Phased Array Ultrasonic Testing vs Computed Radiography Testing - Chris Rawls – Applied Technical Services (ATS)
9:35 am	Coffee Break (Grand Ballroom E, F, G, H – 1st Floor)
9:50 am	Highlights of Dissolving Tank Studies at the University of Toronto - Honghi Tran – University of Toronto
10:30 am	PressureWave+ Technology Overview - John Weimar - GE Power
11:00 am	Multi Hazard Protective PPE - Jim Ellis - W. L. Gore & Associates, Inc.
11:30 am	Recovery Boiler PPE Smelt Deck Protection (Gore & Valmet) - Jim Ellis - W. L. Gore & Associates, Inc.
12:00 Noon	Luncheon (Grand Ballroom E, F, G, H – 1st Floor)
1:00 pm	Flue Gas Cooler - Alec Shull - Andritz

<u>Wednesday, February 2, 2022</u> (continued)

1:35 pm	Pulp Mill Steam Cycle Optimization - Greg Leibel - Babcock & Wilcox
2:10 pm	Improvements to the Recovery Boiler Camera & Best Practices - Chad Cheney - Valmet Automation
2:45 pm	Coffee Break (Grand Ballroom E, F, G, H – 1st Floor)
3:00 pm	Recovery Ash Analyzer and Ash Balance Advisor - Travis Conner - Valmet Automation
3:30 pm	High Velocity Thermal Spray & Modified Alloys for Use in BLRBs - Matt MacWatters - Integrated Global Services (IGS) - Kevin Phillips - Integrated Global Services (IGS)
4:00 pm	Canadian BLRBAC Report - Francis Charette – Suez / Paul Otley – Solenis o Presented by Dean Clay - Boiler Services & Inspection (BSI)
4:05 pm	Finnish Recovery Boiler Committee Report - Emma Kärkkäinen / Antti Tikkanen / Sakari Vuorinen - AFRY o Presented by Dean Clay - Boiler Services & Inspection (BSI)
4:20 pm	BLRBAC Report on 2021 Activities and 2022 Plans - Dean Clay – Boiler Services & Inspection
4:35 pm	BLRBAC ESP Subcommittee – 2021 Incidents ESP Report - Dean Clay – Boiler Services & Inspection
4:50 pm	Closing Remarks
5:00 pm	Adjourn

Presentation from Tuesday February 1, 2022 AF&PA Recovery Boiler Subcommittee Meetings

AF&PA Recovery Boiler Program Status Update
- Wayne Grilliot – AF&PA Recovery Boiler Program

AF&PA POLICY STATEMENT ON COMPLIANCE WITH ANTITRUST LAWS

Fair and vigorous competition is essential to the maintenance of this country's free enterprise system. In furtherance of this principle, all activities are to be conducted in strict compliance with antitrust laws. Staff, officers, directors, members, and committee members are reminded that they are required to comply with the spirit and requirements of the antitrust laws.

A free exchange of ideas on matters of mutual interest to representatives of AF&PA members is necessary for the success of all meetings. Such an exchange of views is essential to the successful operation of every trade association. It is not the purpose of this policy to discourage the exploration in depth of any matters of legitimate concern to meeting participants. Nevertheless, to ignore certain antitrust ground rules, either through ignorance or otherwise, is to create a hazard business people cannot afford.

The Sherman Antitrust Act, The Clayton Act, the Federal Trade Commission Act, and the Robinson-Patman Act comprise the basic federal antitrust laws, which set forth the broad areas of conduct considered illegal as restraints of trade. In general, agreements or understandings between competitors that operate as an impediment to free and open competition are forbidden. The broad language of these laws suggests the scope of federal antitrust prohibitions by forbidding any "agreement or understanding...to substantially lessen competition or tend to create a monopoly in any line of commerce." In particular, the antitrust laws prohibit:

--discussing the fixing or regulating of prices, markups, or the conditions or terms for the sale.

--discussing the establishment of geographic trading areas, allocation of markets or customers, or classification of certain customers as being entitled to preferential treatment.

--discussing or participating in any plan designed to induce any manufacturer or distributor to sell or refrain from selling, or discriminate in favor of or against any particular customer or class of customers.

--discussing limiting or restricting the quantity of products to be produced.

--discussing or participating in any plan designed to control the means of transportation or channels through which products may be sold.

--discussing or participating in any plan which has the effect of discriminating against or excluding competitors.

This is, at best, only a general outline of some of the areas, which pose antitrust dangers in discussions between competitors and between sellers and their customers. They are provided to guide discussion during meetings, and in connection with social or other gatherings on those occasions. Meeting attendees should be familiar with the "Antitrust Guide for Members and Staff of the American Forest & Paper Association". Copies are available from the committee staff executive or the AF&PA Legal Department.

If any question arises about an item on a meeting agenda, it should be reviewed by legal counsel before the meeting. If the question does not arise until the meeting has begun, or if a questionable topic is about to be discussed in connection with any gathering, whether or not a formal meeting, that discussion should be immediately stopped and not resumed until approved by legal counsel.

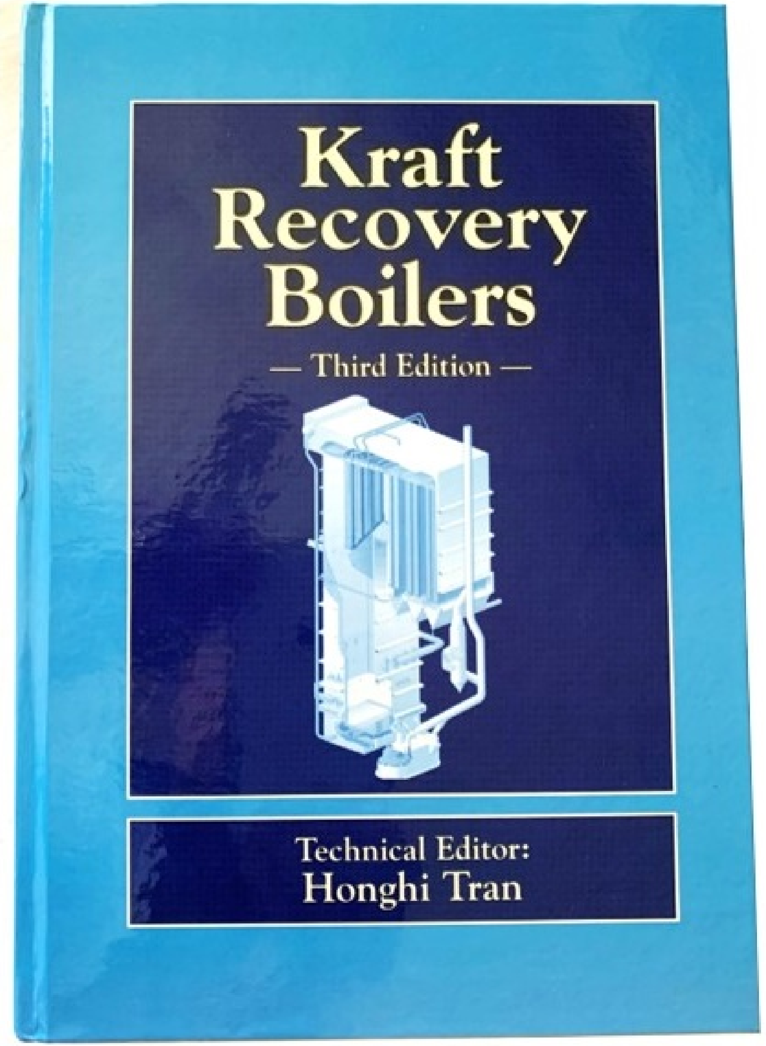
Recovery Boiler Corrosion Environments

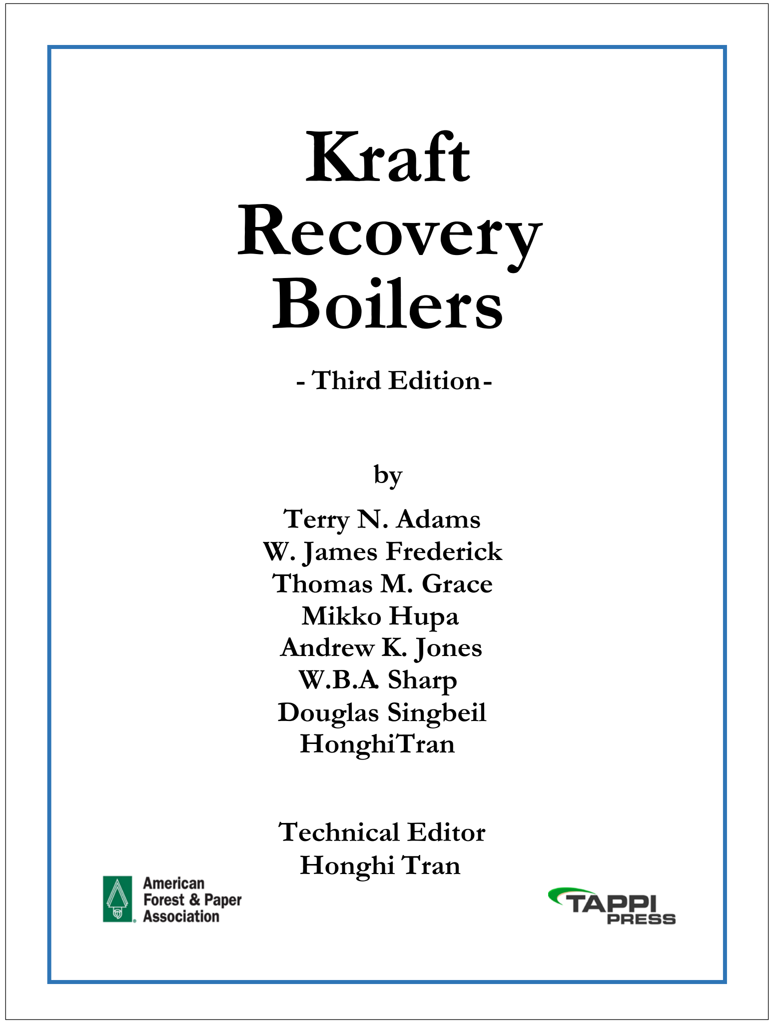
PULP& PAPER
UNIVERSITY OF TORONTO

Honghi Tran

AF&PA Recovery Boiler Program Annual Meeting and Conference
Atlanta, GA, February 2, 2022

Chapter 11 of the Kraft Recovery Boilers Book





Kraft
Recovery
Boilers

- Third Edition -

by

Terry N. Adams
W. James Frederick
Thomas M. Grace
Mikko Hupa
Andrew K. Jones
W.B.A Sharp
Douglas Singbeil
HonghiTran

Technical Editor
Honghi Tran

American Forest & Paper Association

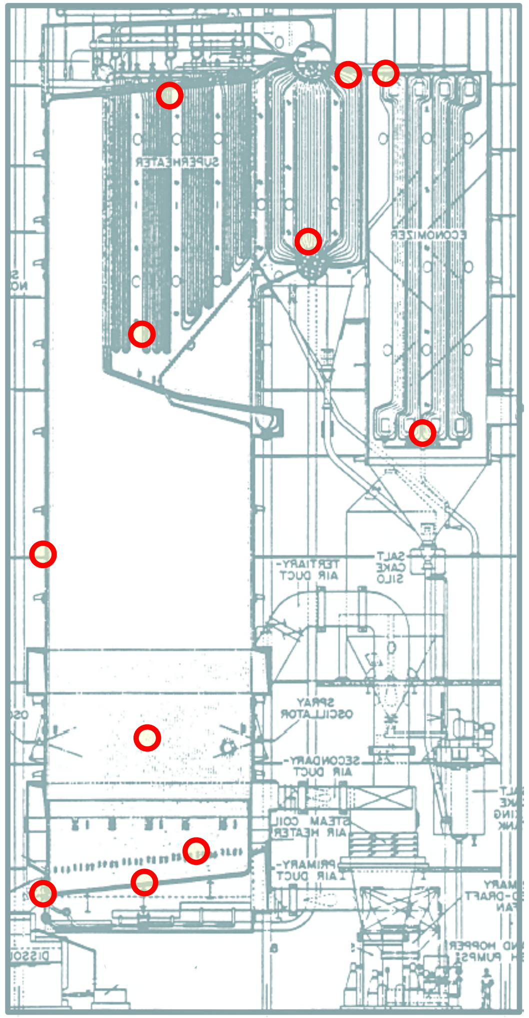
TAPPI PRESS

Chapter 11 – Corrosion Environments

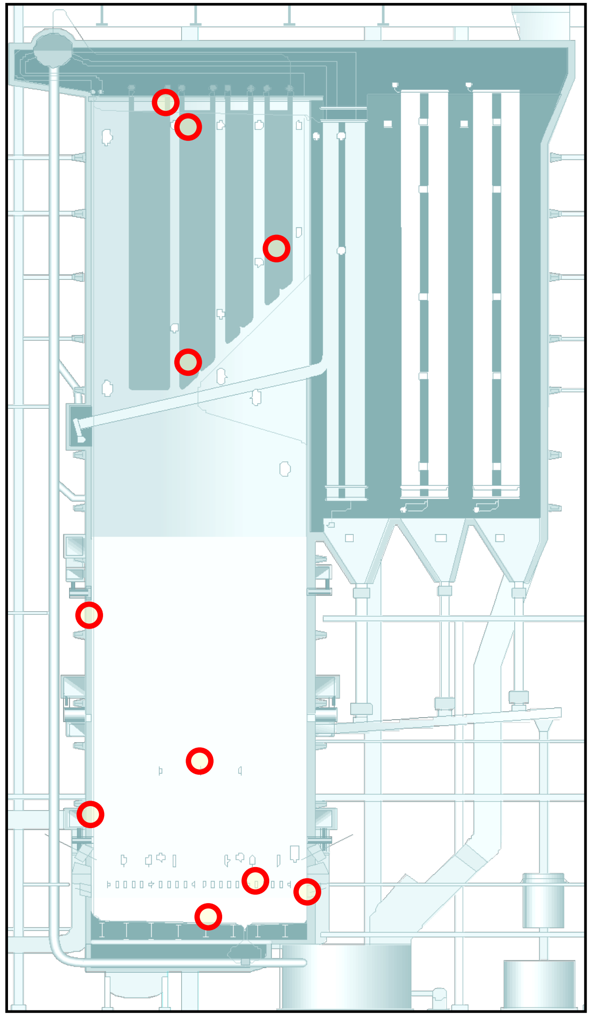
- Authors
  - W.B.A. Sharp and H.N. Tran
- Reviewers
  - Doug Singbeil and Margaret Gorog
- Other Reviewers
  - Christian Thomson
  - Andrew Jones
  - Florence Cone
  - Stephen Cox

Common Problem Locations

Two Drum Boiler



Single Drum Boiler



Common Problem Locations

- Corrosion and cracking of tubes occur virtually everywhere in the boiler from the lower furnace to upper furnace and to electrostatic precipitator
- Older two-drum boilers experience more corrosion but less cracking problems than modern single drum boilers
  - Carbon steel (CS) is less corrosion resistant than stainless steel (SS)
  - CS has a lower thermal expansion coefficient than SS → less susceptible to cracking

Trends and Impact on Boiler Corrosion

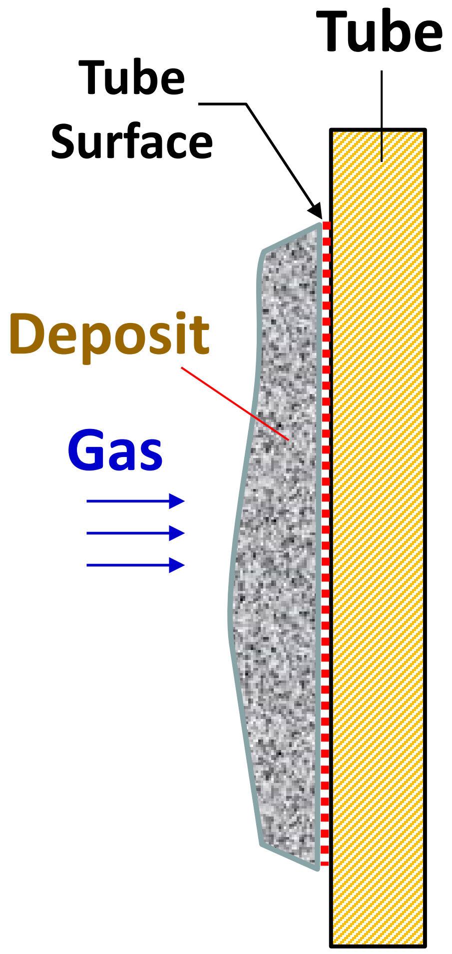
- Changes in the recovery process and boiler operation have led to increased corrosion rates.
  - High steam temperatures and pressures
  - High solids (80^{+}%) firing
  - Increased hardwood pulping
  - Minimizing chemical losses
  - Increasing liquor sulfidity due to high sulfur concentrations waste streams recovery
- These process changes alter flue gas and tube surface temperature distribution in the boiler, flue gas composition, and deposit thermal properties and corrosivity

Corrosion Control

- Vitally important for the safety and productivity of recovery boiler/mill operations
  - Tube leaks can result in catastrophic smelt-water explosions
  - Tube replacement is expensive and requires long boiler downtime
- To understand how tubes are corroded, it is important to consider the environments to which they are exposed

Basic Requirements for Corrosion to Occur

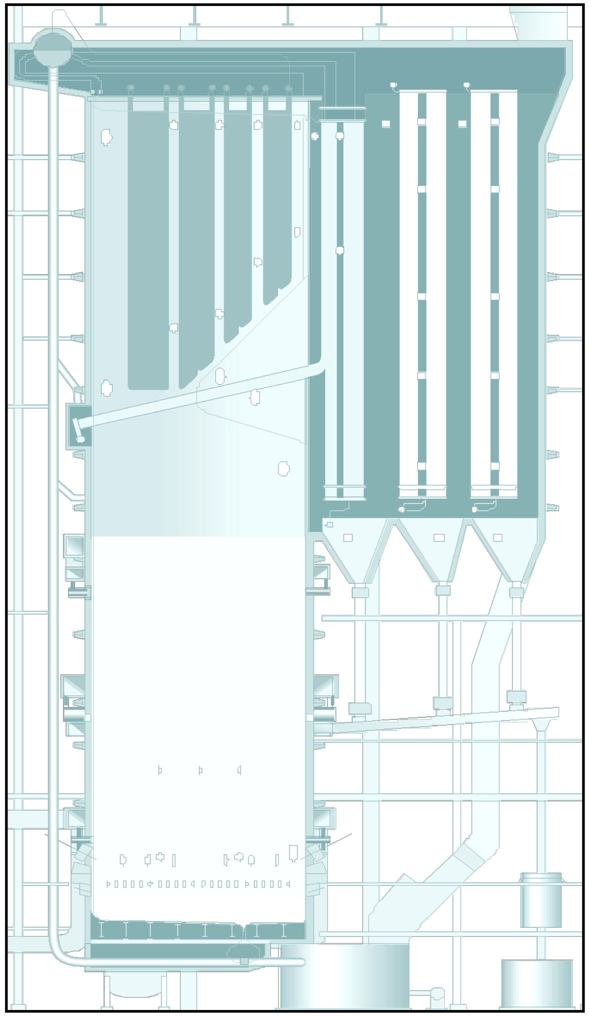
- Tube
  - Tube surface material
- Corrosive environment at the tube surface
  - Flue gas composition, deposit composition, or both
  - Temperature
- Time



Corrosion Environments are Different

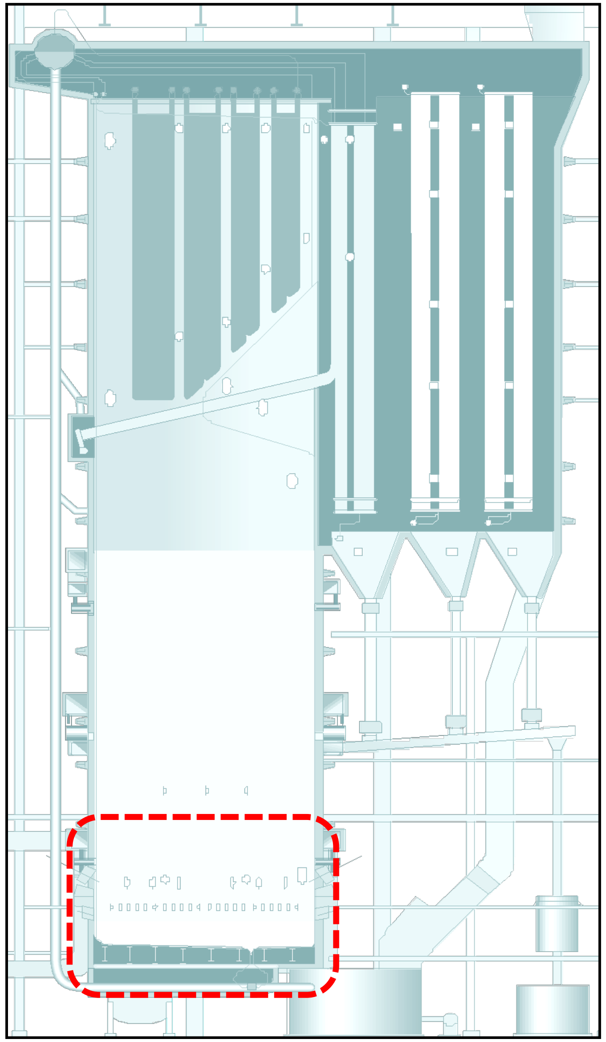
Due to the difference in:

- Tube material and
- Tube temperature
- Gas composition (reducing vs. oxidizing)
- Gas temperature
- Corrosive deposits
  - Molten deposits
  - Wet deposits



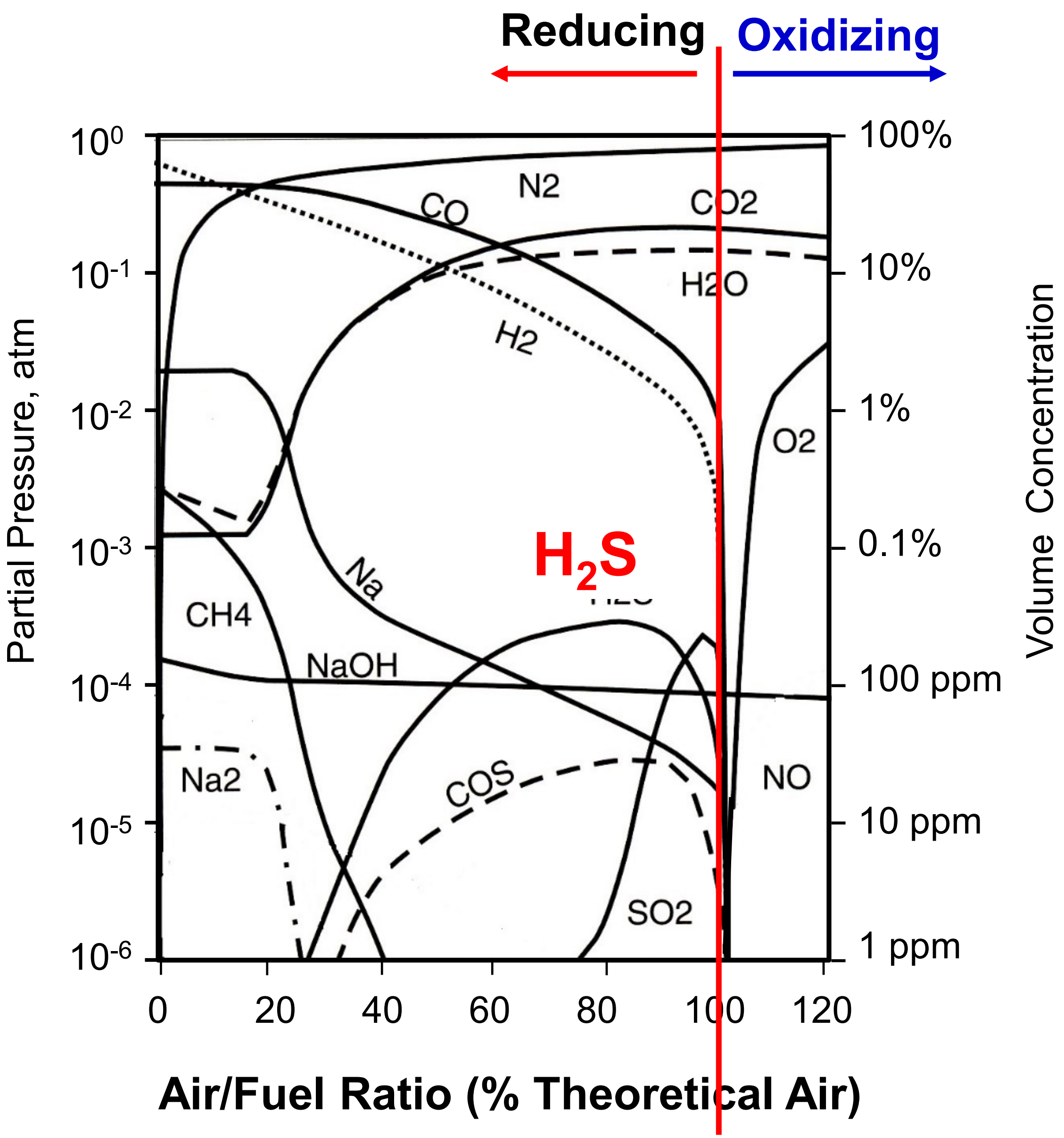
Corrosion in the Lower Furnace

- Strong reducing atmosphere
- Gas phase sulfidation corrosion
- Carbon steels corrode very fast in boilers operated above 62 bars (900 psi) ➔ high temperature
- Composite tubes or weld overlaid tubes are typically used



Effect of Air/Fuel Ratio on Gas Composition

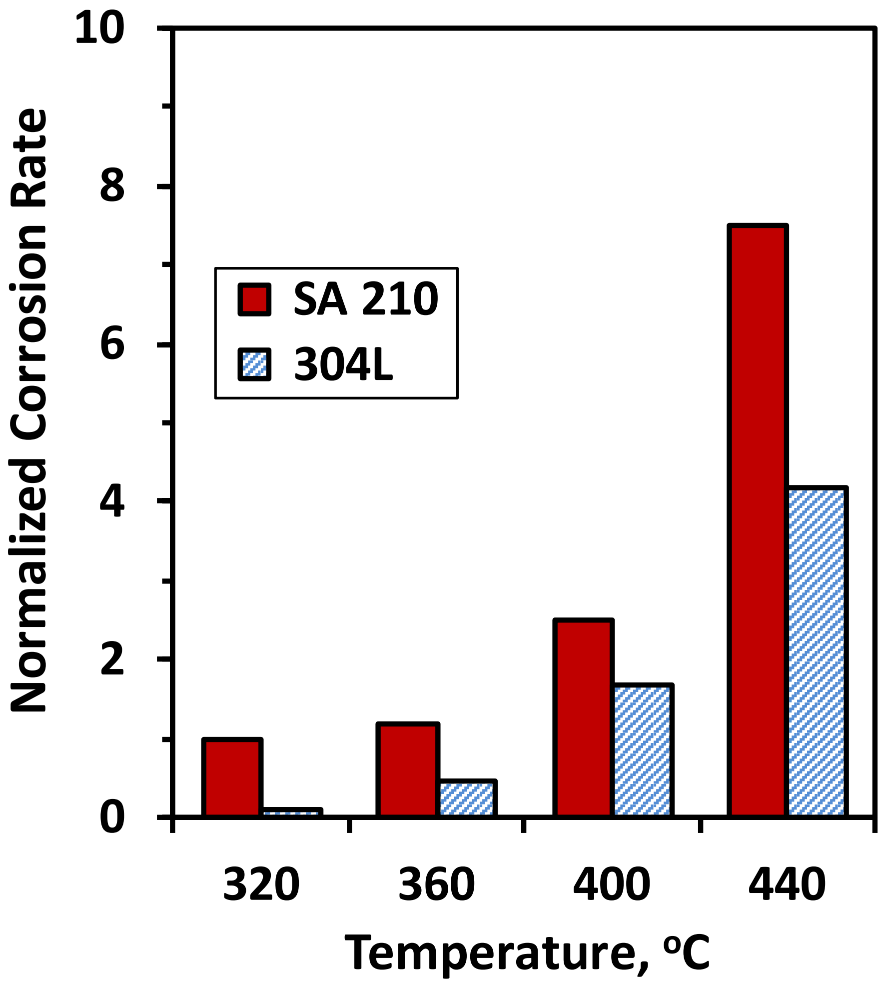
- Corrosive sulfur gases (mainly H_2S) exist in the lower furnace environment



Hupa, M (Kraft Recovery Boilers- 3rd Ed. Chapter 2)

Corrosion Rates of SA 210 and Type 304L

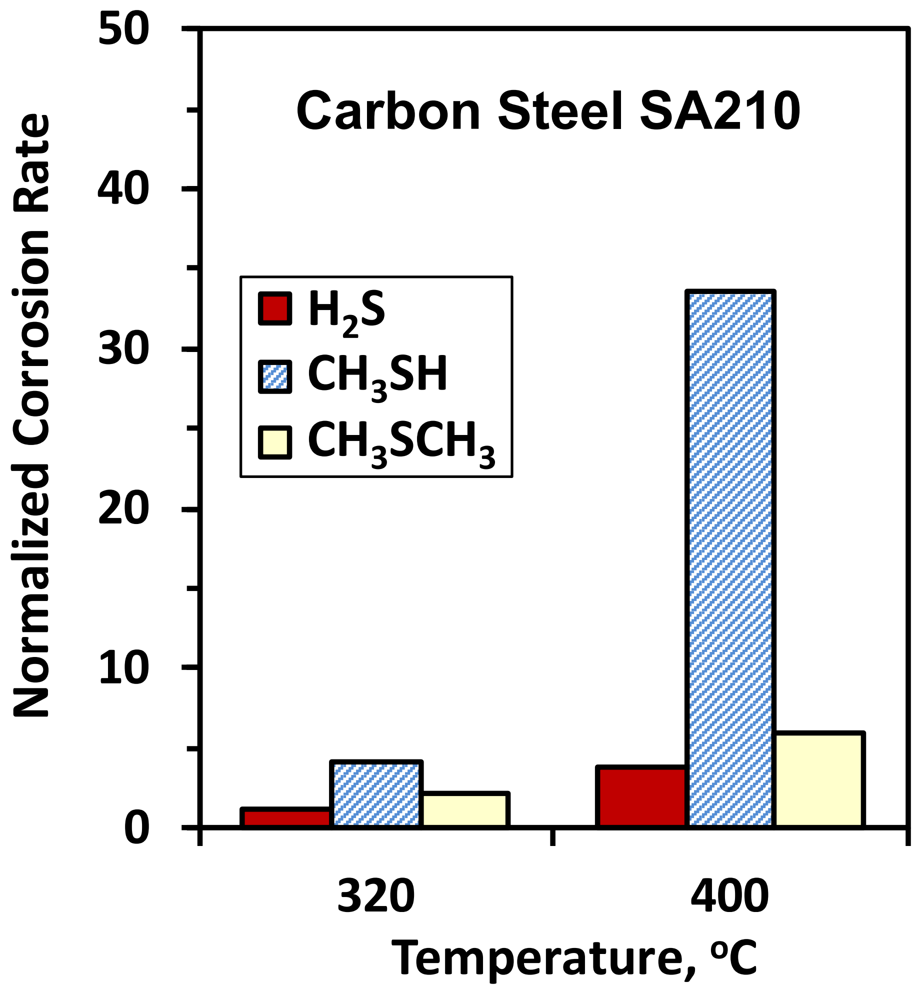
In 1% H_2S - 99% N_2 gas mixture



- Corrosion rate increases exponentially with temperature
- Carbon steel SA210 corrodes at a much higher rate than stainless steel 304L

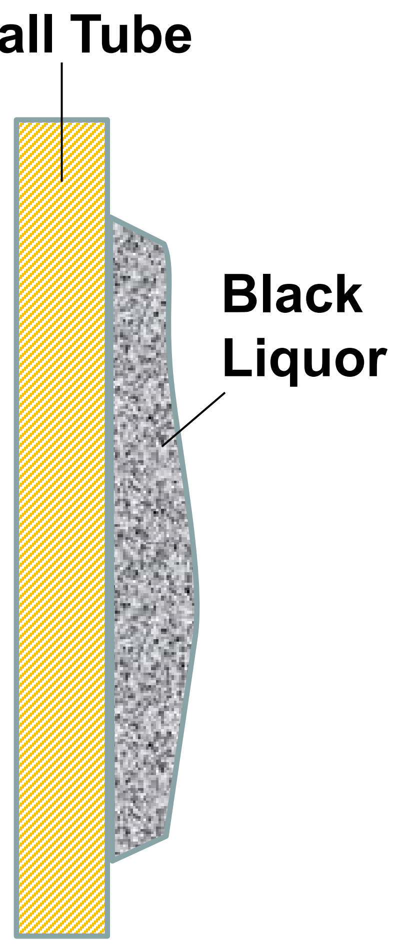
Corrosion Rates of SA 210

In 1% sulfur gas - 99% N_2 mixture



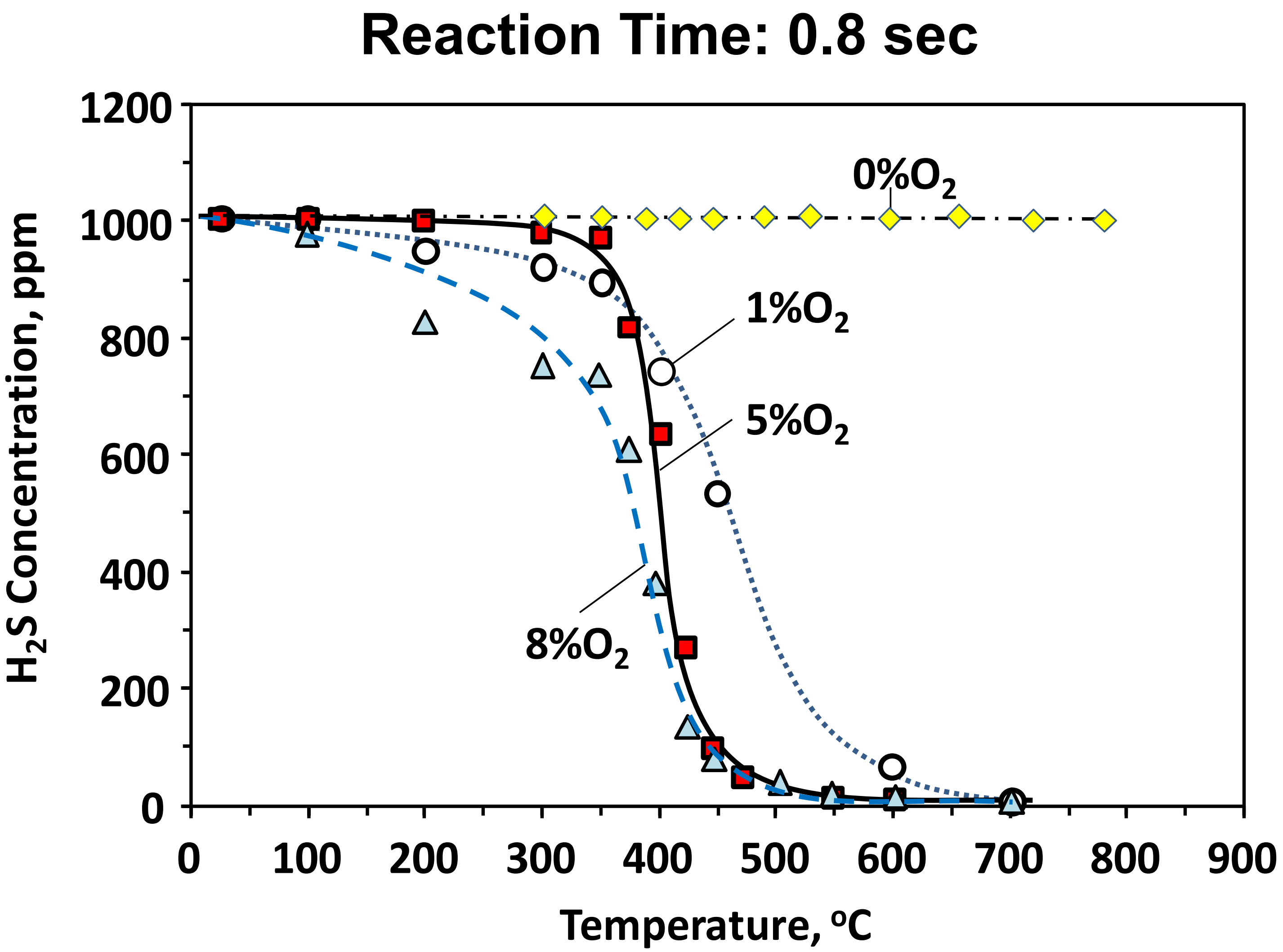
- Corrosion rate increases with temperature
- Of these TRS gases, methyl mercaptan is the most corrosive

Formation of Corrosive Sulfur Gases During Black Liquor Drying and Pyrolysis



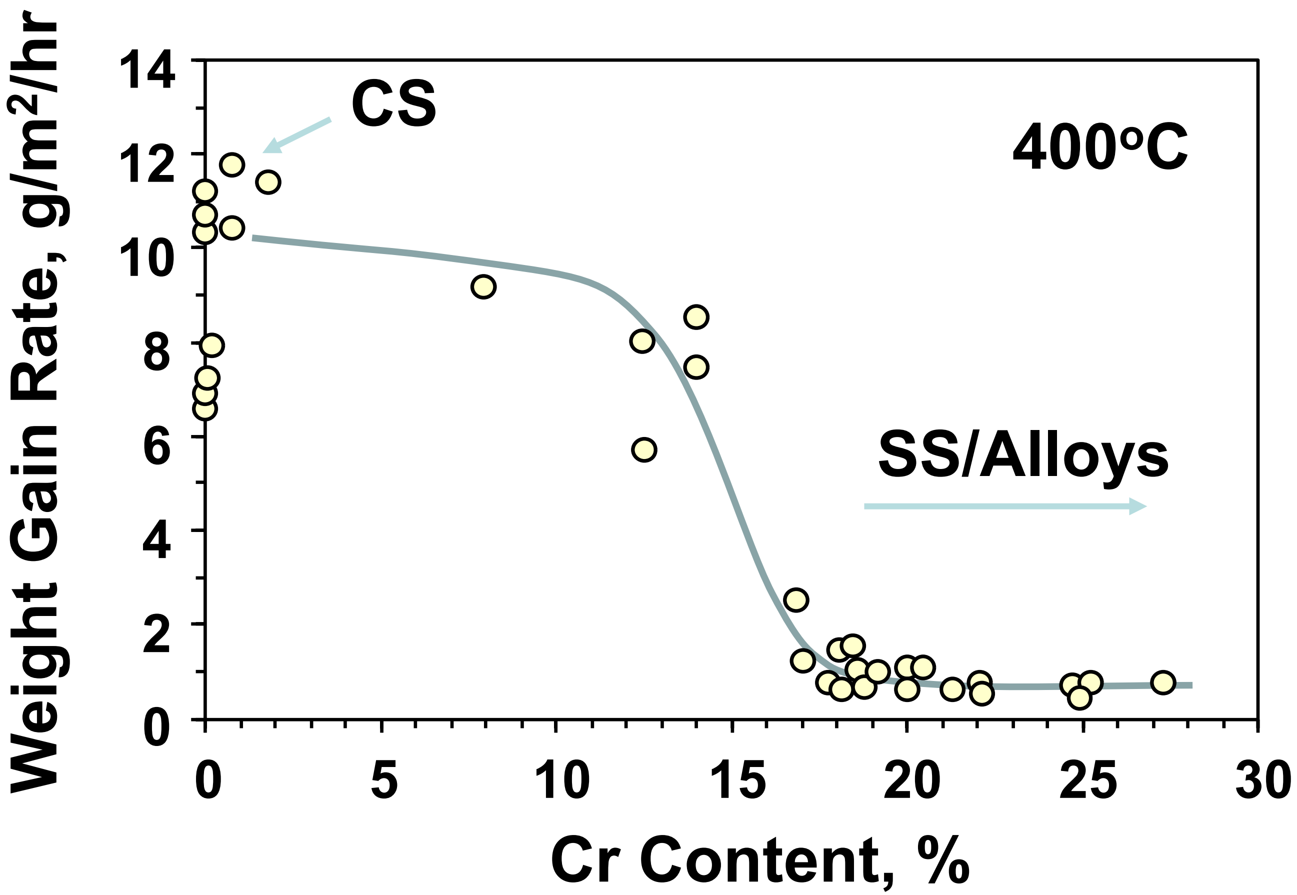
- Reduced sulfur gases (particularly CH_3SH) are released during black liquor drying and pyrolysis
- Avoiding black liquor spraying on wall tubes helps minimize corrosion

Oxidation of H_2S

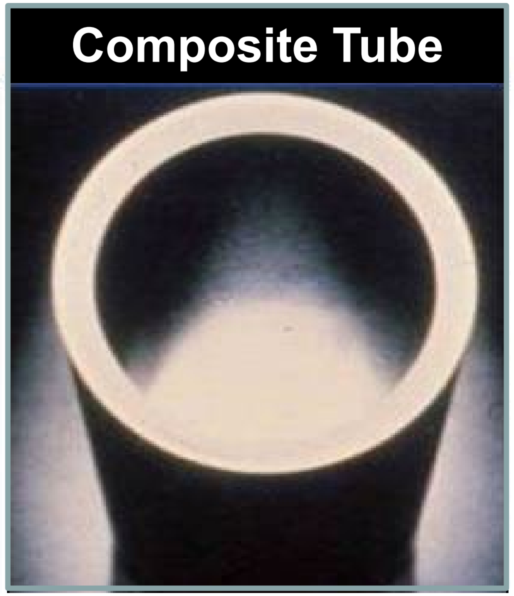


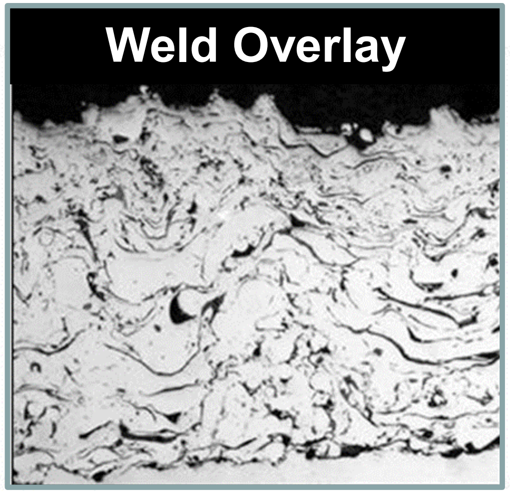
- Below 350°C (660°F), H_2S cannot be oxidized readily
- A large concentration of H_2S can exist at the tube surface
  - Forms a corrosive environment for carbon steel

Effect of Cr on Corrosion Resistivity



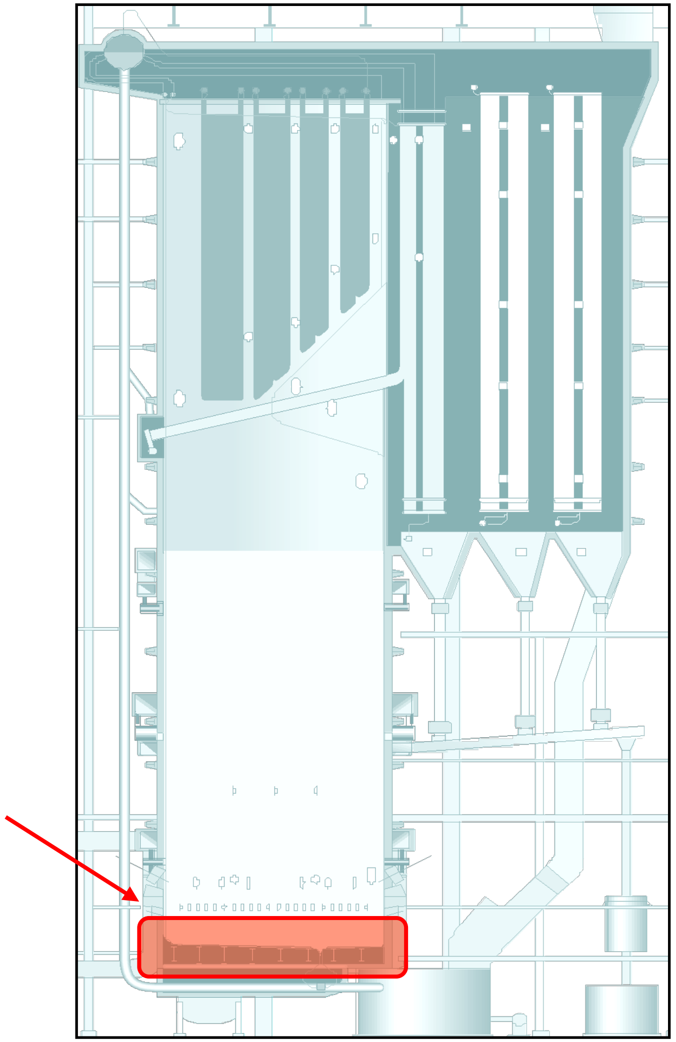
Moberg, 1974





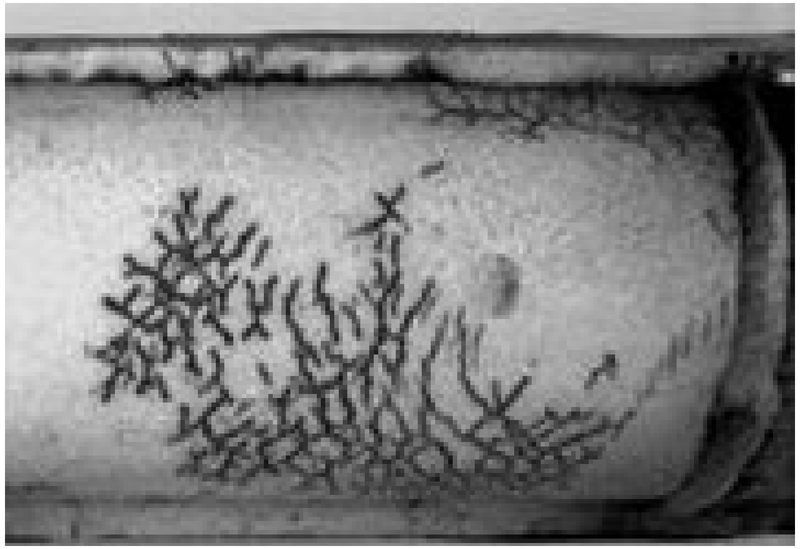
Cracking in Composite Floor Tubes

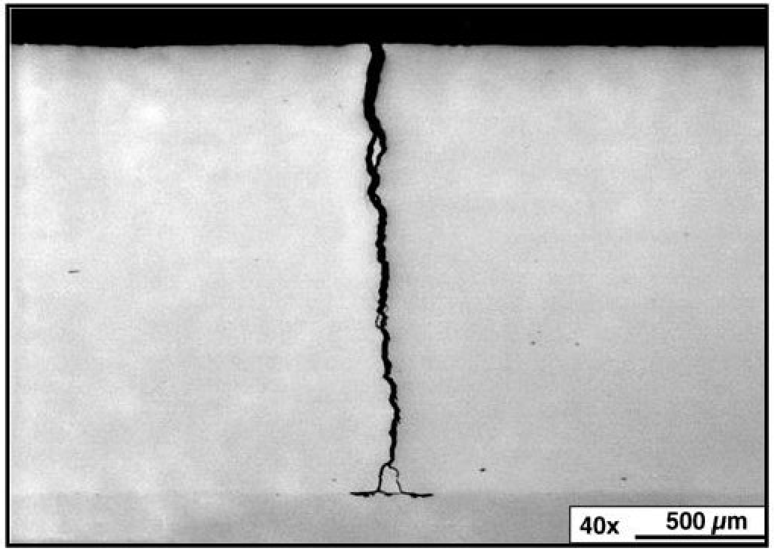
- For boilers with composite tubes, most cracks occur near spout and primary air port openings (higher T and ΔT)
- Cracks stop at SS/CS interface
- Many boilers replaced composite tubes with Alloy 825 or 625

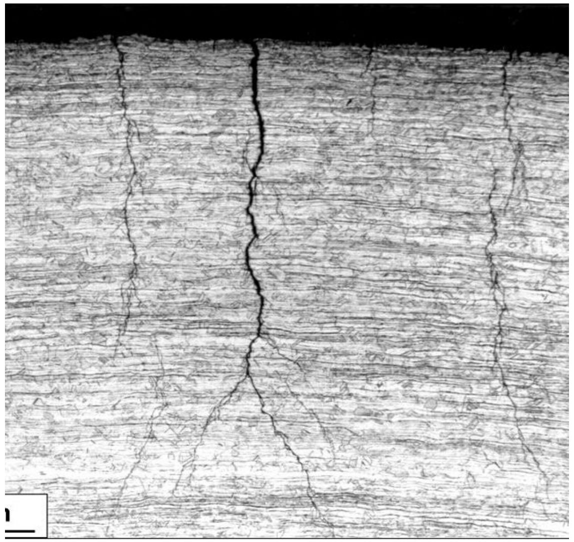


Cracking in Composite Floor Tubes

- Operational temperature cycles leave SS layer in tension
- Stress corrosion cracking (SCC) initiates during shutdowns in concentrated solution of dissolved smelt (160 - 200°C); propagates by thermal fatigue

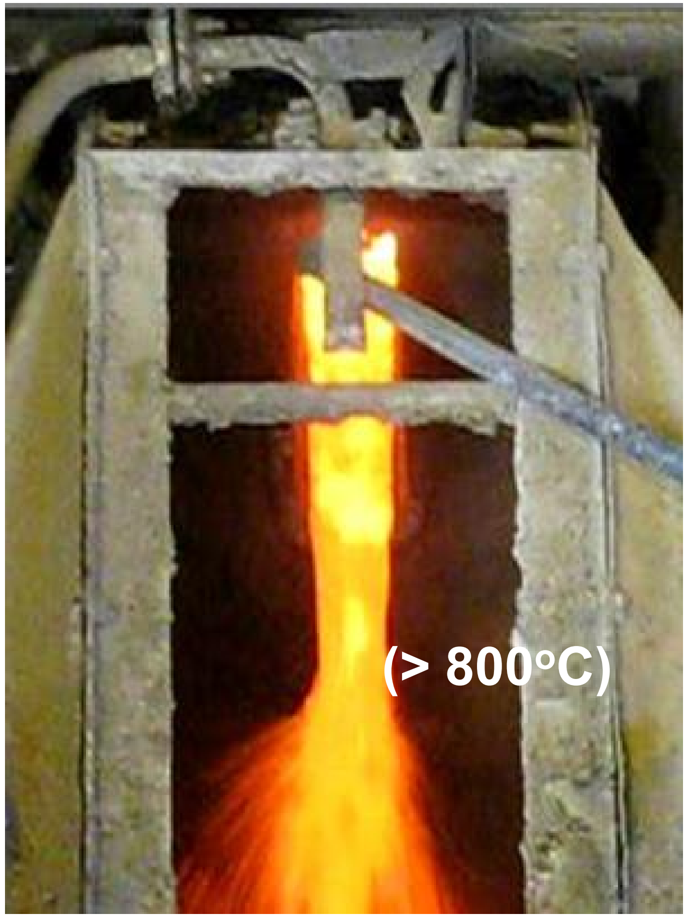






Corrosion in Flowing Smelt Environment

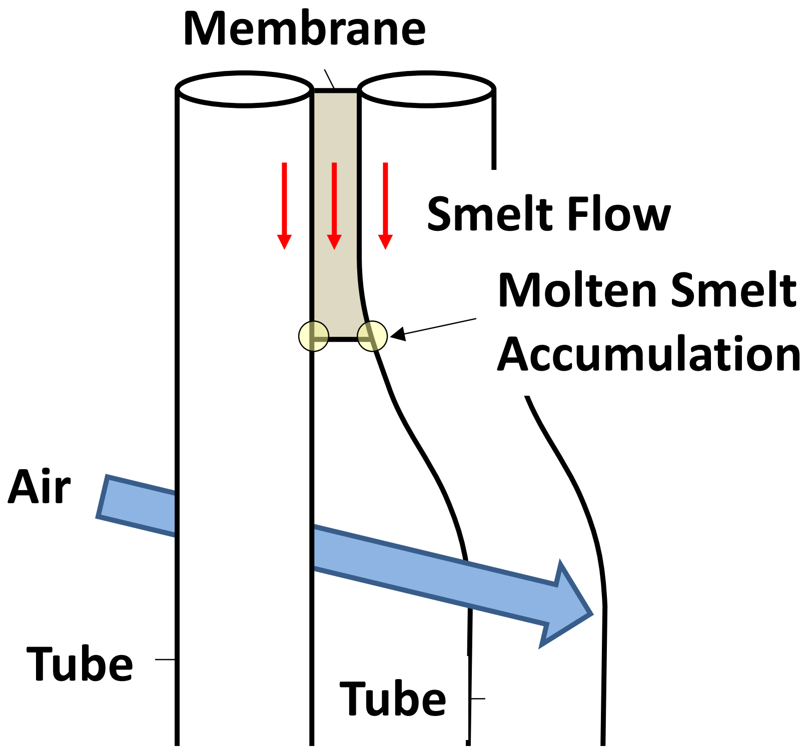
- Smelt spouts are typically made of carbon steels
  - Rates up to 1.3 m/y on carbon steel if metal reaches smelt temperature (> 800°C)
- Keep spouts cool (BLRBAC)
  - Lower spout metal temperature by 22°C (40°F) can increase spout life 4 times
- Some mills use chromized or SS-clad spouts



Corrosion of Primary Air Ports made of Composite Tubes – Cold side

- Caused by molten NaOH
- NaOH condenses where CO_2 and SO_2 concentrations are low
- NaOH/Na_2CO_3 mixture can melt at tube surface temperature, dissolving the protective Cr_2O_3 on SS 304L
  - 4 NaOH + Cr_2O_3 +3/2 O_2 → 2Na_2CrO_4 + 2H_2O

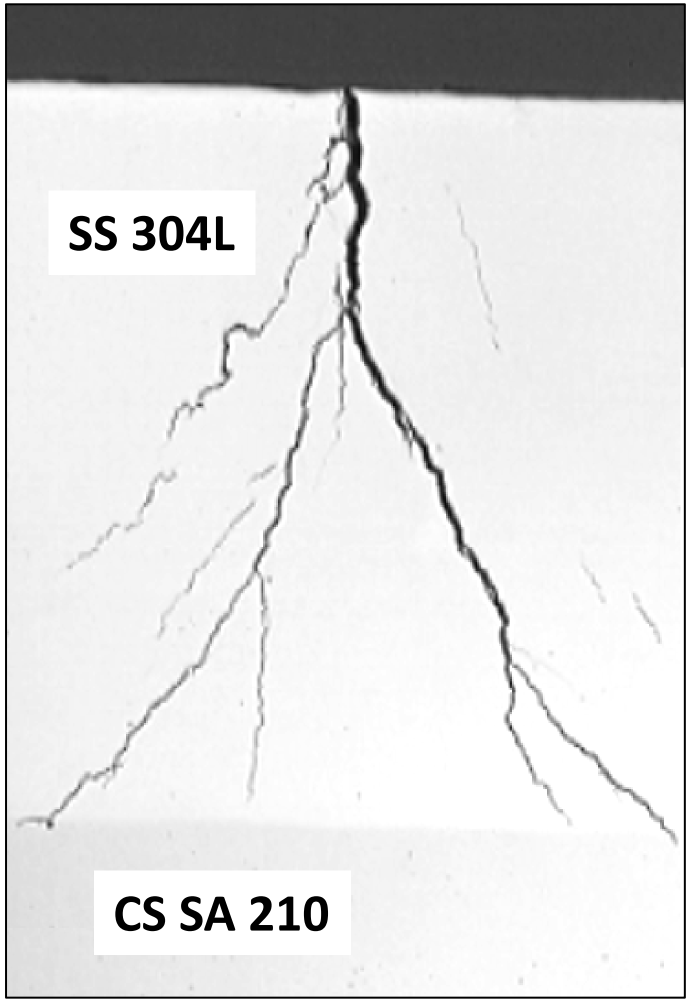
Corrosion of Primary Air Ports made of Composite Tubes – Fireside



- Corrosive environment resulting from molten smelt dripping

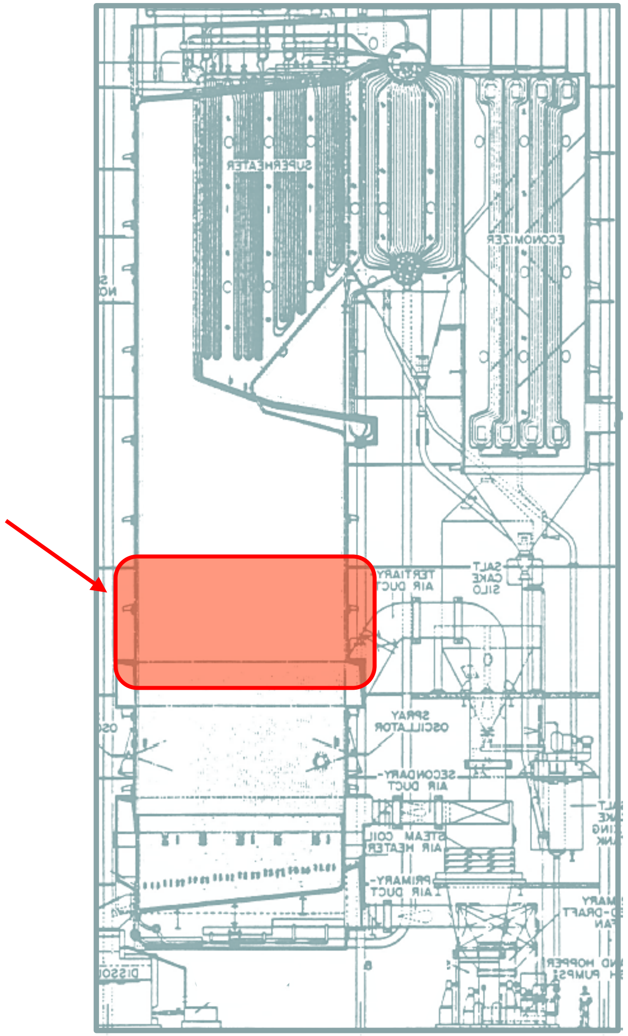
Cracking in Composite Air Port Tubes

- Initiated by SCC or thermal fatigue
- Propagated by thermal stresses
  - where smelt washes against tubes and at attachment welds
- Cracks can propagate into carbon steel
  - CS steel can contain residual tensile stress from bending
- Thermal stresses can be minimized by
  - Stabilizing boiler operation
  - Minimizing thermal strains by using Alloy 825-clad tubes



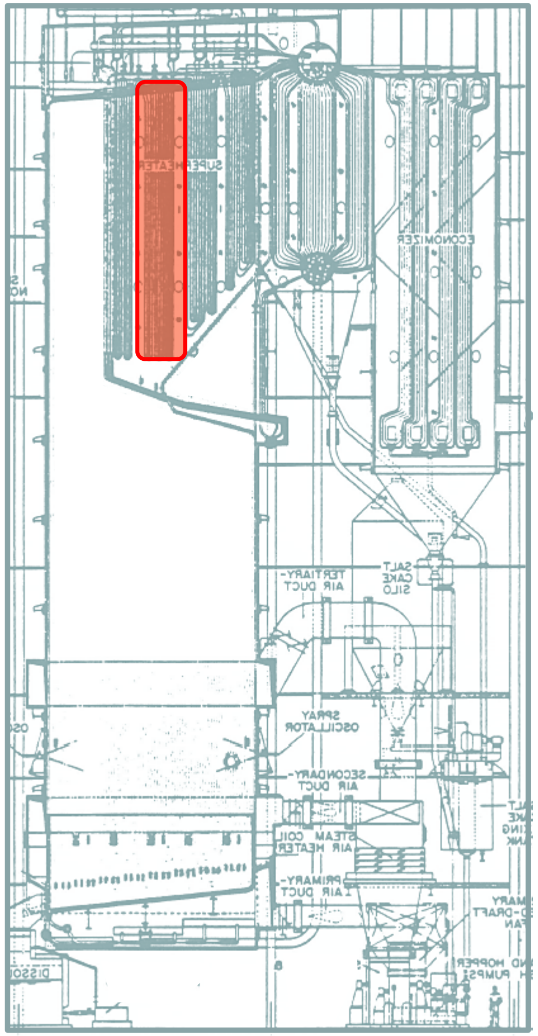
Corrosion in Mid Furnace

- Reducing atmosphere
- Gas phase sulfidation corrosion, mainly by H_2S
- Occurs mostly on carbon steel tubes above the composite tube line



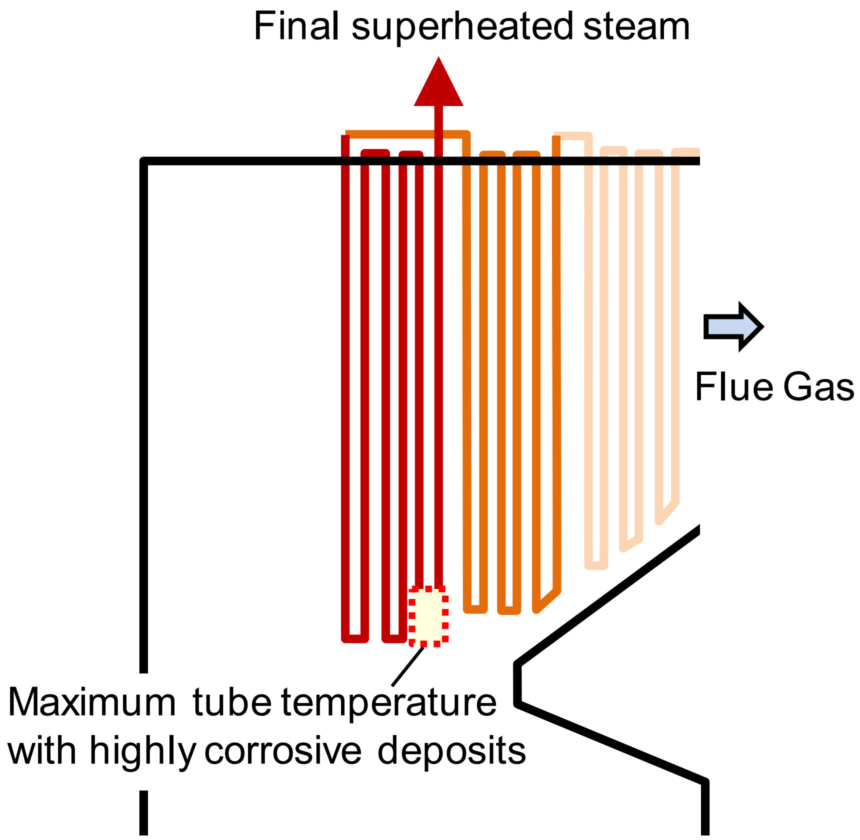
Corrosion in the Superheater Region

- Alternate reducing/oxidizing atmosphere
- Corrosion types
  - Gas phase, sulfidation and molten salts
- Tube temperature exceeds deposit first melting temperature (FMT)
  - FMT is controlled mainly by potassium (K) content
- Chloride (Cl) makes the environment more corrosive
  - Increasing deposit molten phase
  - Forming HCl gas

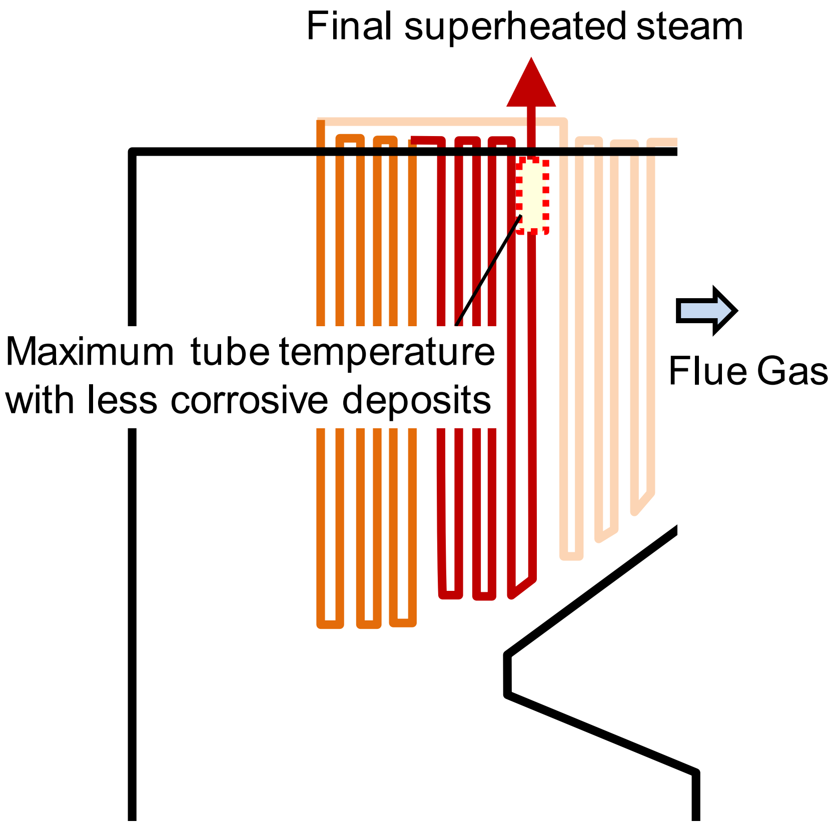


Effect of Steam Flow Configuration on SH Deposit Corrosivity

Counter-current design

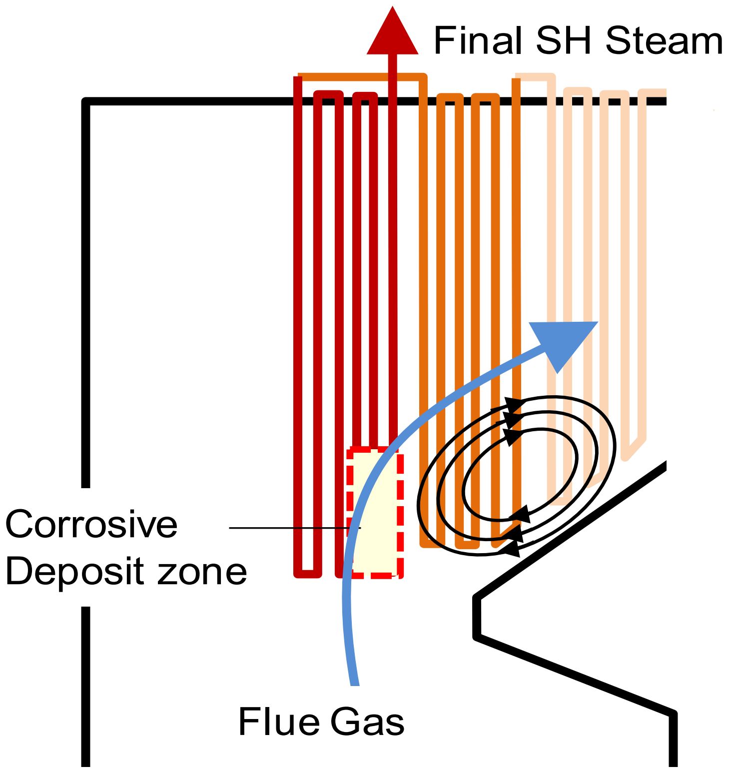


Co-current design

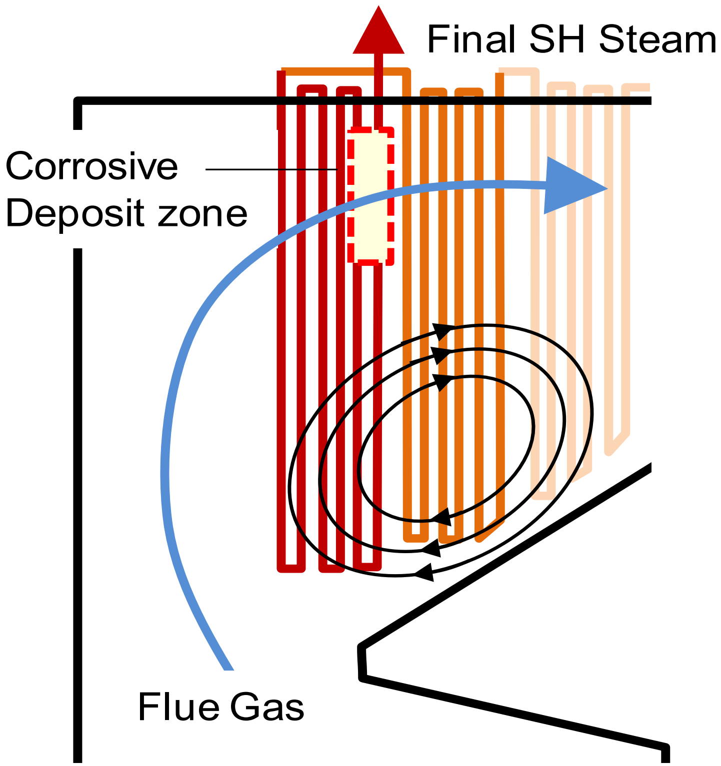


Effect of Bullnose Size on Gas Recirculation and Corrosive Deposit Zones

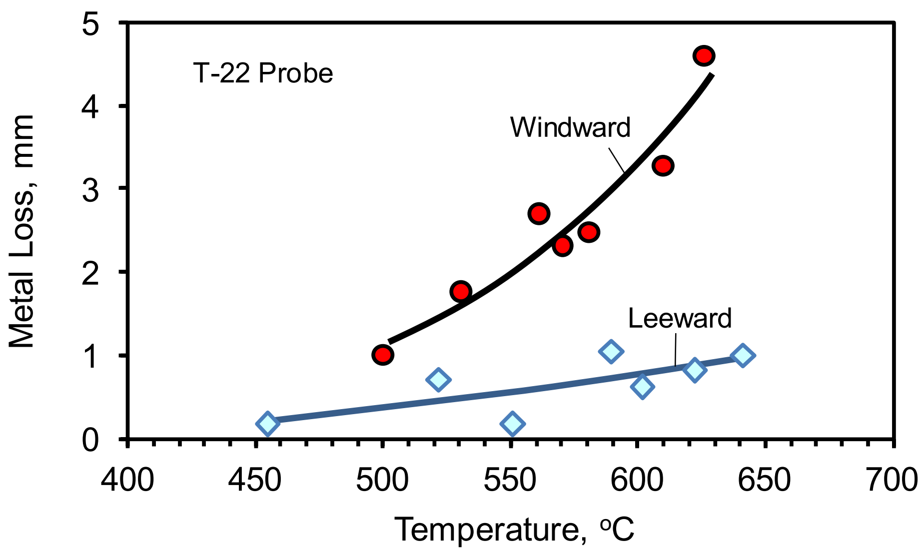
Small Nose Arch

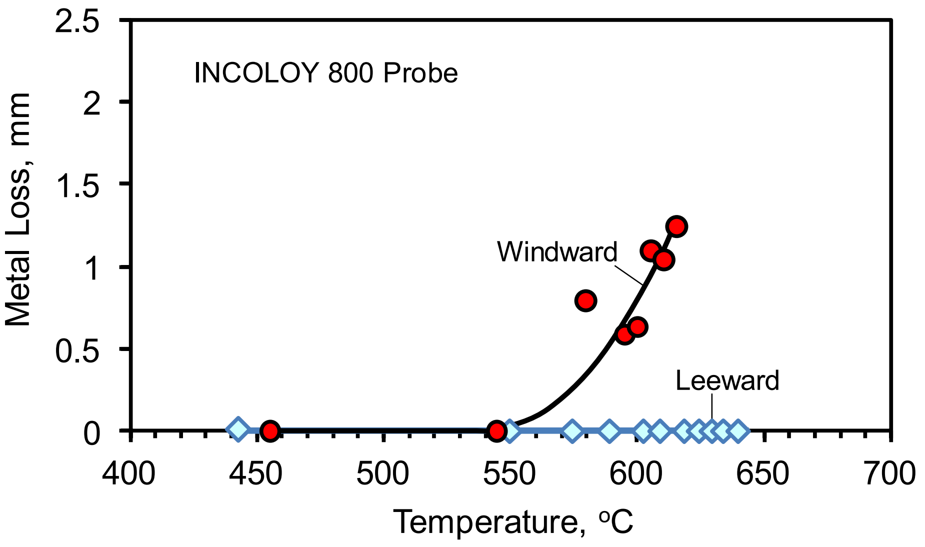


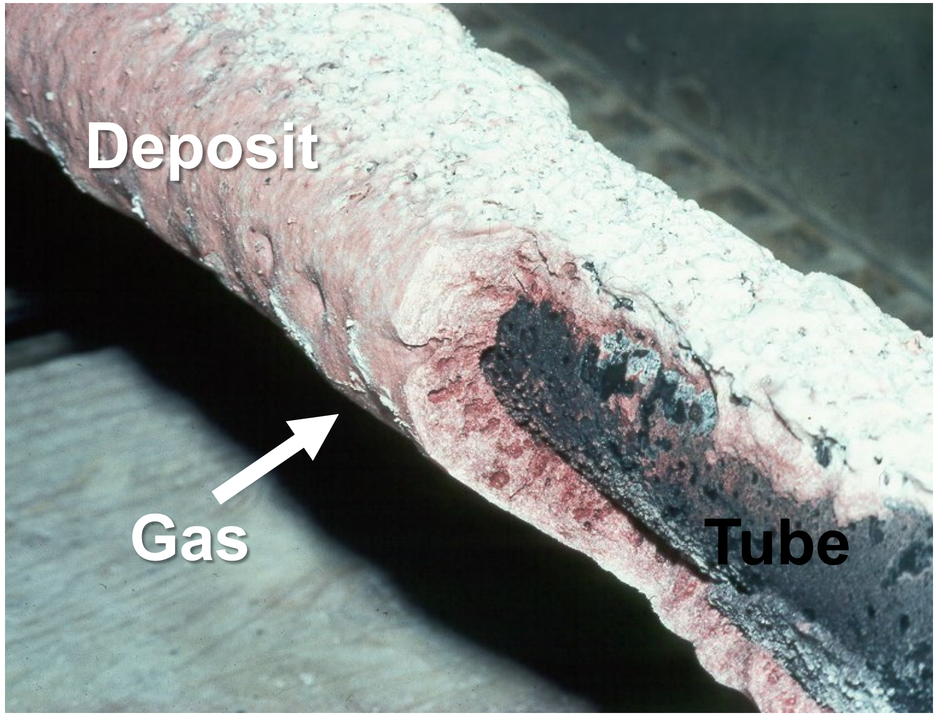
Large Nose Arch



Superheater Deposit Corrosivity







Superheater Deposit Corrosivity

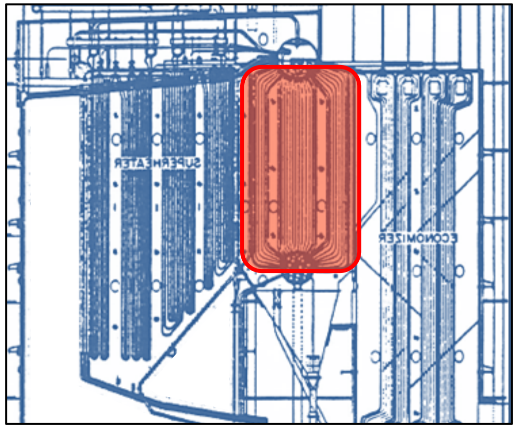
- Most recovery boiler superheater corrosion is caused by either oxidizing or reducing environments or by molten salt corrosion.
- Problems arise when locally high tube temperatures exceed the first melting temperature (FMT) of surface ash deposits.

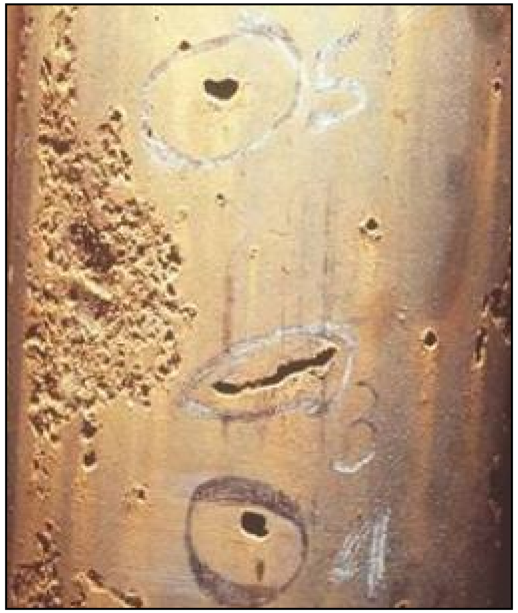
Tube Materials used in Superheater Region

- CS T11 tubes may be used in boilers with steam temperature below 450°C
- T22 may be used up to <480°C
  - Solid 347H SS or composite 310/T22 tubes are more preferable if concerned about risk of SCC
- Incoloy 800 or SS 310 or equivalence must be used in boilers operated above 480°C

Corrosion of Boiler Bank Tubes

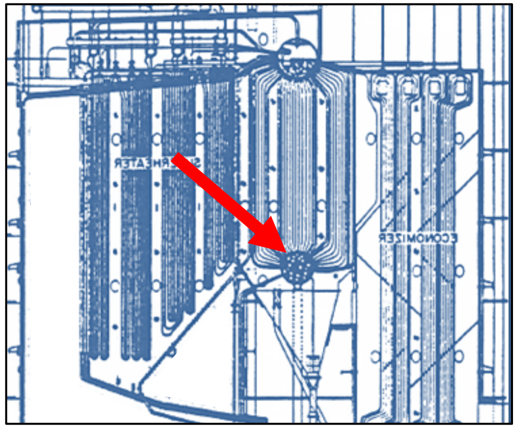
- Caused mostly by acidic sulfates
  - $Na_2SO_4 + SO_3 + H_2O \rightarrow NaHSO_4$
- Risk of bisulfate pitting is highest in low pressure boilers with
  - low bed temperatures, low solids firing
  - high sulfur input and intense sootblowing

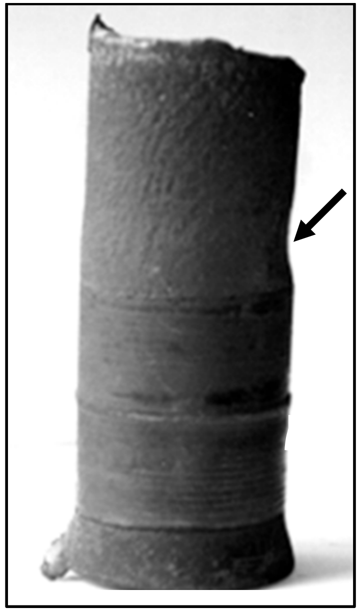


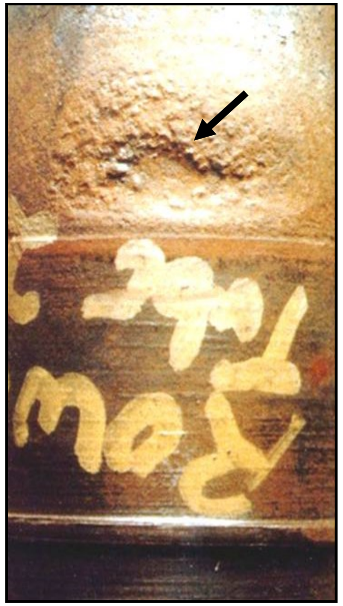


Near-Drum Thinning

- **Near-Drum Thinning**
  - Corrosion potentially caused by acidic bisulfate ($NaHSO_4$) formed at tube surface
  - Erosion by water droplets from sootblower jet
- **Stress Corrosion Cracking (SCC) in drum itself**
  - where alkali concentrates from water chemicals by leaks at tube-to-drum seals







Economizer, Precipitator and Stack

- Flue gases are oxidizing and cool; corrosion damage is rare
- Tubes may suffer dew point corrosion, sootblower erosion, or outside-in fatigue cracking
- Below water dew point (68 - 77°C moisture condenses
  - Flue gases, e.g. SOx, NOx dissolve in condensate
  - pH falls to 3.0 - 2.5
  - CS corrodes at up to 0.76 mm/y, (0.030”/y)

Summary

- **Understanding the conditions and environments that cause corrosion and cracking enables us to minimize the problems by addressing the underlying cause of each type of damage**

Butt Weld Examinations with:

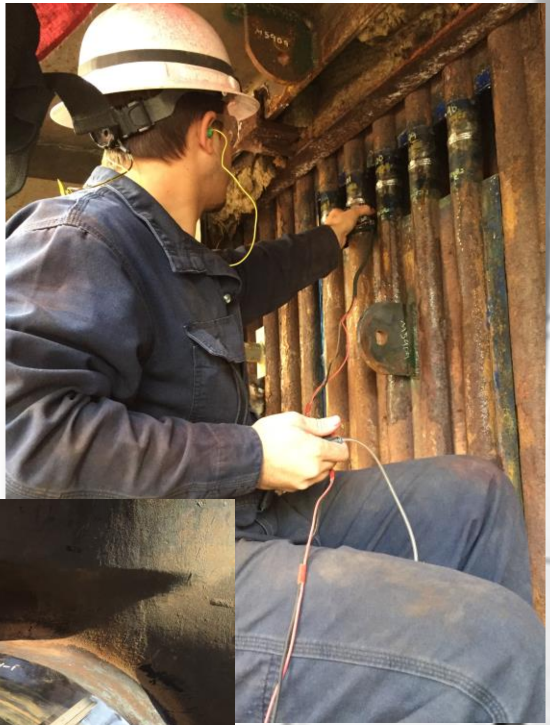
Phased Array Ultrasonics

vs.

Radiography

Christopher A. Rawls
ASNT Level III
Applied Technical Services

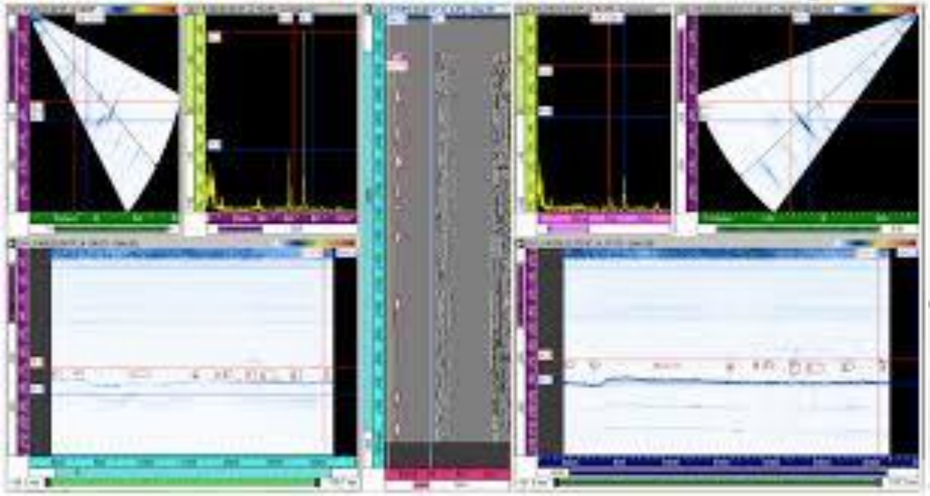
Phased Array Ultrasonic Examination (PAUT)



Phased Array Ultrasonic Examination (PAUT)

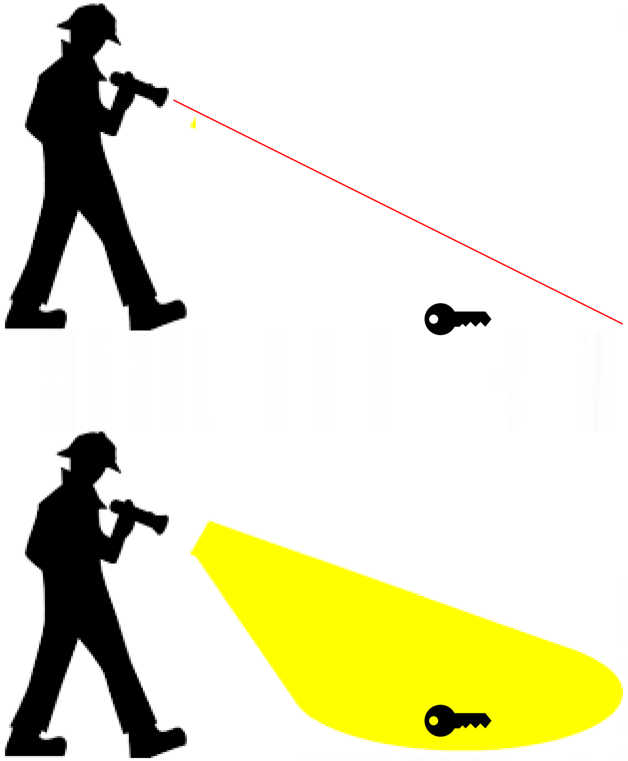
Major Benefits

- Safety
  - No Radiation Area
  - No need For RSO
  - No Chance of Radioactive Exposure
- Time
  - No Shot Windows
  - Faster Turnaround for Repairs
  - Less Time between Welding and Examination
- Permanent Record of Examination
  - Compared with conventional UT



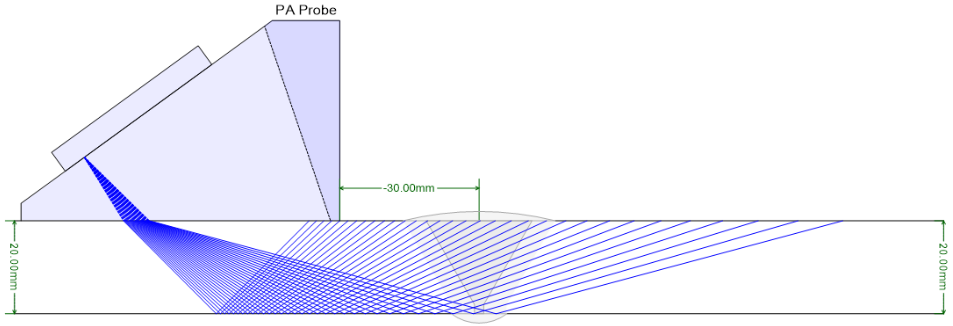
Phased Array Ultrasonic Examination (PAUT)

- PAUT vs Conventional UT
  - Conventional UT is like trying to find your keys in the dark with a laser pointer
  - Phased array is like using a flashlight

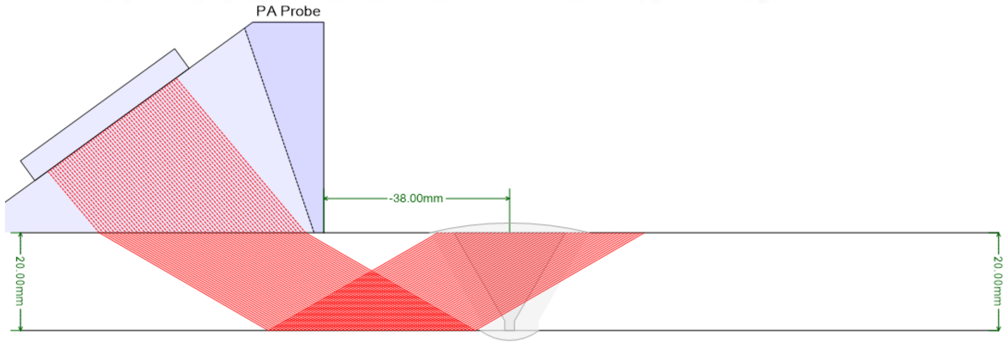


Phased Array Ultrasonic Examination (PAUT)

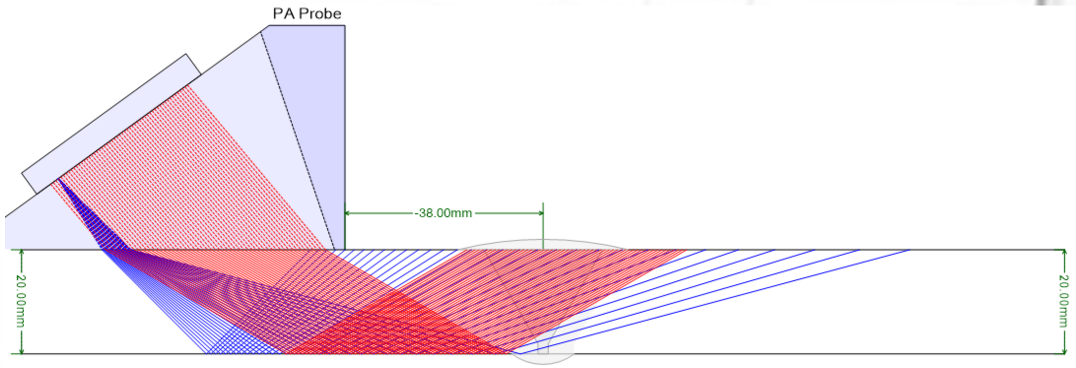
- Arrays can be utilized to create multiple angles generating a much broader area of inspection (S-scan)



- Arrays can also utilize multiple elements (beams) all at the same angle (E-scan)



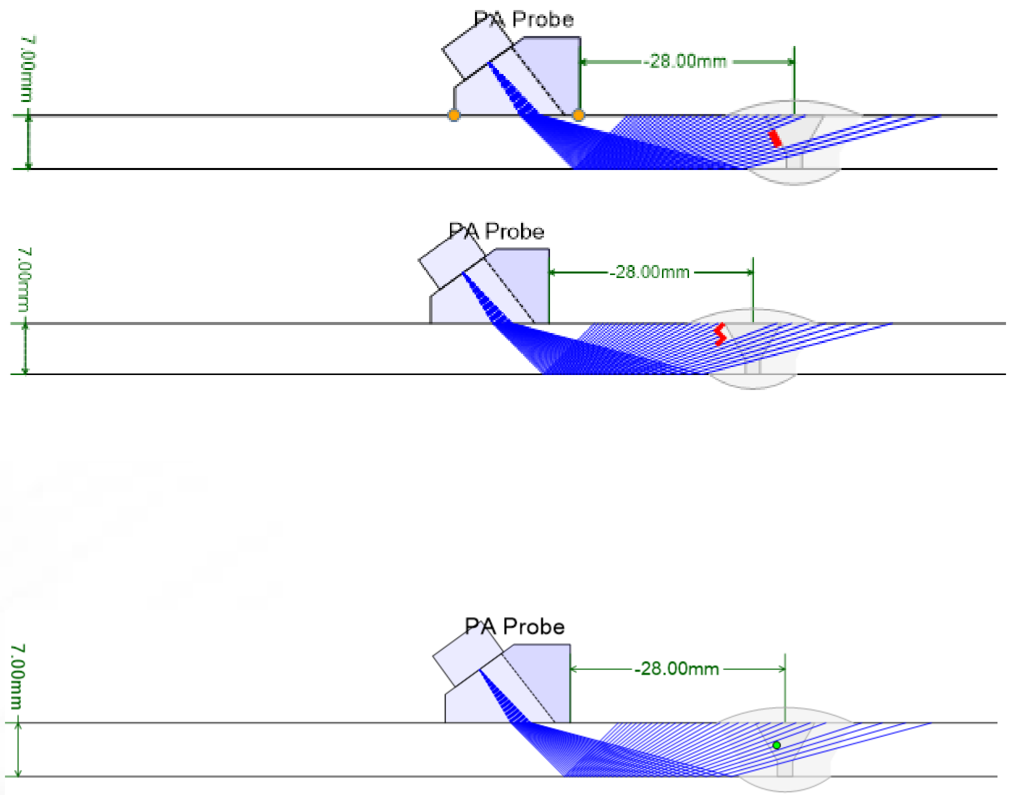
- Multiple groups can be used to incorporate the advantages of Both E-scans and S-scans



Phased Array Ultrasonic Examination (PAUT)

- Manual applications CAN be used which have the advantages of the broad examination area… however
  - This still leads to full dependence on the examiner and leaves you with no data for future review
- Computer based acquisition (required by ASME Sec I, ASME B31.1. and ASME Sec VIII) utilizin encoded scanners will allow for a permanent record of the examination

Phased Array Ultrasonic Examination (PAUT)



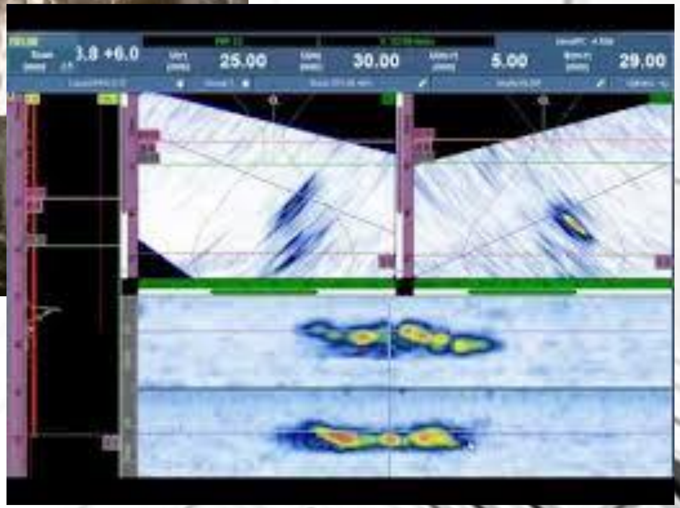
- Defects Easily Detected
  - Cracks
  - Lack of Sidewall Fusion
  - Lack of Root Penetration
- Defects Less Easily Detected
  - Porosity
  - Small Slag Inclusions
  - Small Inter-bead Lack of Fusion

Phased Array Ultrasonic Examination (PAUT)

- Calibration Blocks Required for each Application
  - ±25%T
  - 0.9≤ D ≤1.5

- Membrane Interference

- More Difficult to Interpret than RT



Phased Array Ultrasonic Examination (PAUT)

Code Compliance

1. ASME B31
    1. PAUT is Required for B31.1 (Scan Will be Recorded)
    2. B31.3 can use Conventional UT… But why would you?
2. ASME Sec VIII (UT in Lieu of RT)
    1. ASME Sec VIII Div.2
    2. Aspect Ratio (Fracture Mechanics) Acceptance Criteria
    3. Demonstration Blocks
3. API (Storage Tanks)
    1. Automated Systems
    2. Additional Certification Requirements



Radiography

Radiographic Exposure Device

- Iridium 192
- Cobalt 60
- Selenium 75
- X-Ray Tubes
  - Golden Tubes

Imaging Media

- Conventional Film
- Computed Radiography (CR)
- Digital (or Direct) Radiography (DR)

Radiography

Ir-192 (Iridium)
0-3” Steel
- Film
- CR
- DR

X-Ray Tube
0-1” Steel
- CR
- DR

Co-60 (Cobalt)
0-9” Steel
- Film
- CR
- DR

Se-75 (Selenium)
0-2.5” Steel
- CR
- DR

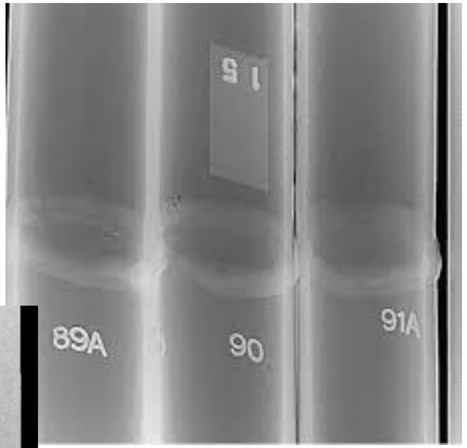
Radiography

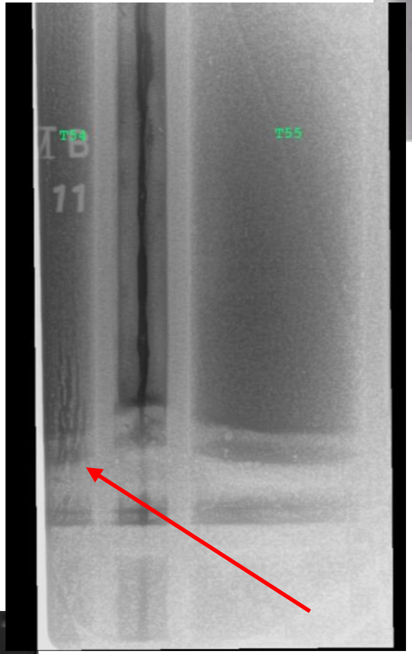
- Conventional – Best Overall Quality
  - Similar to 35mm Film vs. Digital Camera
- Computed Radiography
  - Less Intense Radiation Required than Conventional Film to create image
  - Flexible Imaging Plates, can be cut to many sizes (can fit many applications)
- Digital Radiography
  - Less Exposure Time Required than CR to create image
  - No need to develop or process images, can have results almost instantaneous

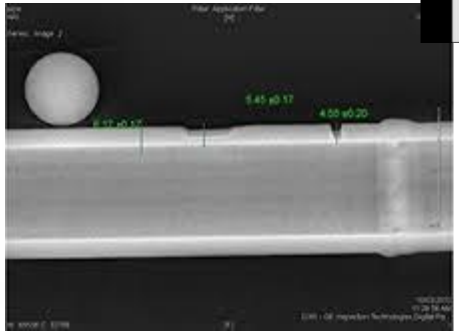
Radiography

Major Benefits

- The overall latitude of Radiography is unparalleled.
  - No need for specific calibration blocks for different material or size components
    - Boiler tubes
    - Headers
    - piping
  - Ability to perform Weld Quality, Informational, and Exploratory inspection
    - Butt Welds
    - SACC
    - Profile Thickness
  - Ease of interpretation





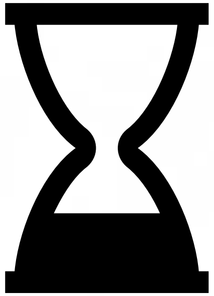


Radiography

<u>Exclusionary Zones</u>

- Iridium 192
  - 5.2 R/Ci/Ft
  - $I_1 / I_2 = D^2_2 / D^2_1$

- 50 ci of Ir-192
  - 424'
  - 4HVL Collimator = 90'
  - 30 minutes of exposure = 45'



Code Compliance

- What does the code allow me to use for weld inspections???
  - ASME B31.1 – Radiography (Conventional, CR, and/or DR), and encoded Ultrasonics (PAUT)
  - ASME B31.3 – Radiography (Conventional, CR, and/or DR), manual or encoded Ultrasonics
  - ASME Section I - Radiography (Conventional, CR, and/or DR), and encoded Ultrasonics (PAUT)
  - ASME Section VIII

Code Compliance (cont.)

- Code Compliance for Boiler Components other than tubes is critical, this includes:
  - Header Welds
  - Drum Welds
  - Attemperator Welds
  - Feedwater Piping Welds
  - Etc.

- ASME Sec I Acceptance Criteria is not written to account for Boiler Tube Butt Weld
  - TAPPI TIP 0402-31 states "Acceptance criteria for weld quality and action resulting from non-conformance must be specified by the mill"

Questions???

Point of Contact – Bill Castle
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770-853-3761

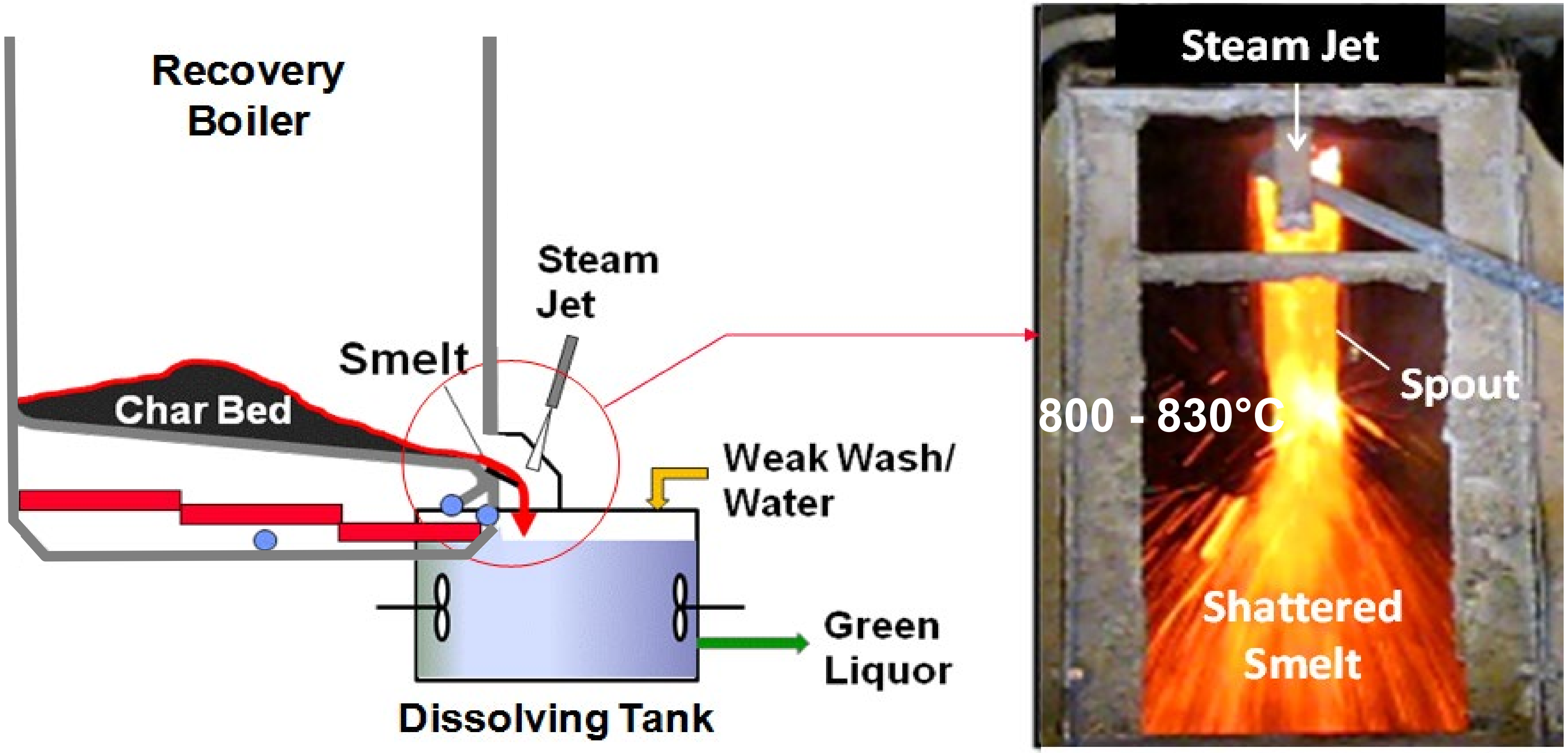
Highlights of Dissolving Tank Studies at the University of Toronto

PULP& PAPER
UNIVERSITY OF TORONTO

Honghi Tran, Markus Bussmann and Willy Wong

AF&PA Recovery Boiler Program Annual Meeting and Conference
Atlanta, GA, February 2, 2022

Smelt Dissolving Tank (SDT) Operation



Problems in SDT Operation

- Noisy/violent smelt-water interaction
- Jellyroll smelt formation
  - Flow disruption
  - Smelt runoffs
  - Operational safety
- Inconsistent green liquor properties
  - Flow, temperature, concentration (TTA, density)
- Hard scale formation

SDT Safety Research at U. of Toronto

- On-and-off since 2001, but mor "official" since 2011
- Jointly supported by
  - University-Industry research consortia
  - NSERC (Natural Sciences & Engineering Research Council of Canada)
  - AF&PA Recovery Boiler R&D Subcommittee (Sept. 2016 – Aug. 2019)
- Performed by
  - 6 professors
  - 8 graduate students (2 PhD, 6 Master's)
  - 1 research associate (Sue Mao)
  - 2 undergraduate students

Research Projects Undertaken To Date

- Molten smelt viscosity/fluidity
- Jellyroll smelt formation mechanisms
- Smelt run-offs (field studies)
- Hard scale formation (tank walls, floor and agitators)
- Molten smelt/steam jet interaction
- Molten smelt/water interaction
- Frozen smelt dissolution kinetics
- Acoustic analysis
- Hydrodynamics/mixing

16 technical papers published

AF&PA Projects (Sept. 2016 – Aug. 2019)

- **Effect of high sulphate levels on molten smelt viscosity**
- **Interaction between highly viscous smelt and water**
- **Dissolution kinetics of solid smelt as a function of green liquor concentration and temperature;**
- **Development of an algorithm to identify the onset of violent dissolving tank operation**

Key results were presented at the last AF&PA Recovery Boiler Program Annual Meeting and Conference in February 2020

This Presentation

Address the following questions:

1. **How does the high sulphate content in smelt affect smelt viscosity?**
2. **Can viscous smelt be shattered?**
3. **How does SDT operation affect frozen smelt dissolution?**
4. **What is the status of the SDT acoustic model development?**

1. Effect of Sulfate on Smelt Viscosity

PULP&PAPER
UNIVERSITY OF TORONTO

THE EFFECT OF HIGH SULPHATE CONTENT ON MOLTEN SMELT VISCOSITY

Prepared For

American Forest & Paper Association
Recovery Boiler R&D Subcommittee
1101 K Street, N.W., Suite 700, Washington, D.C. 20005

By

Honghi Tran and Markus Bussmann*
Pulp & Paper Centre, and
Department of Chemical Engineering & Applied Chemistry
University of Toronto, Toronto, ON, Canada

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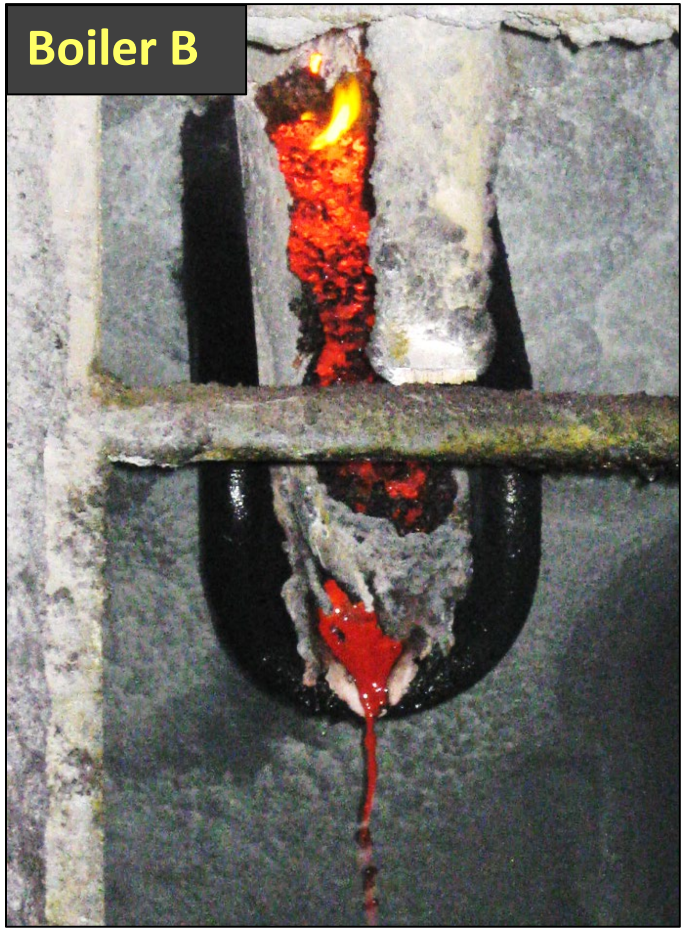
University of Toronto, Toronto, ON, Canada

September 28, 2021

Highly Viscous Smelt = “Jellyroll” Smelt

- Smoothly flowing smelt suddenly becomes sluggish and forms a viscous blob on the spout trough



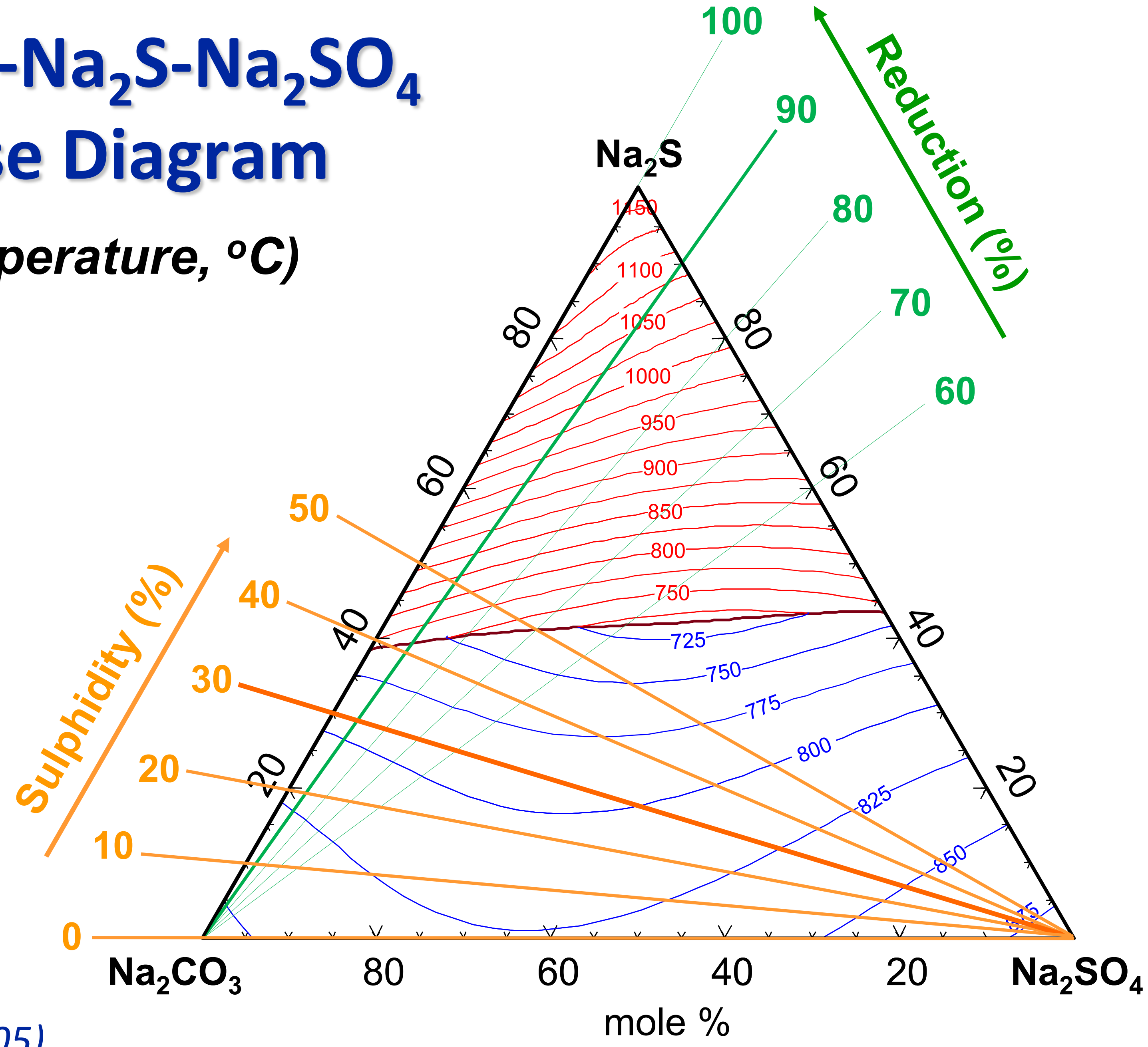
What Do We Know about Jellyroll Smelt?

- Formed by 3 main mechanisms
  - Smelt freezing, fallen deposits and char inclusion
- Compared to molten, fluid smelt, jellyroll smelt
  - Is much more viscous → Can't be shattered readily
  - Contains more sulfate and less sulfide
  - Contains more char
  - Moves slowly through spout troughs
  - Enters the dissolving tank in large lumps

Would the high sulfate content increase the smelt freezing temperature, making it easier for the molten smelt to freeze, and to become more viscous?

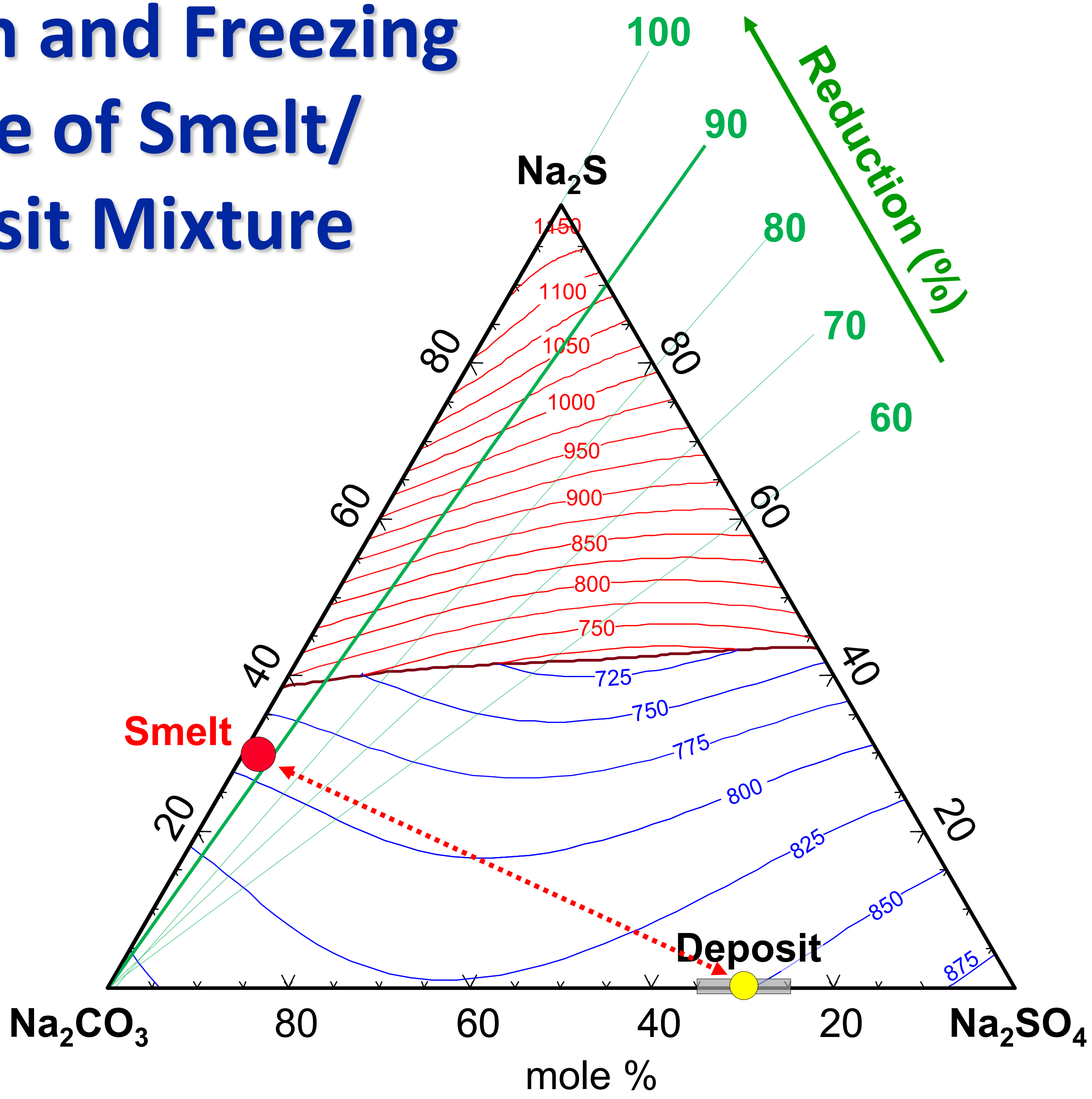
Na_2CO_3-Na_2S-Na_2SO_4 Phase Diagram

(Temperature, °C)



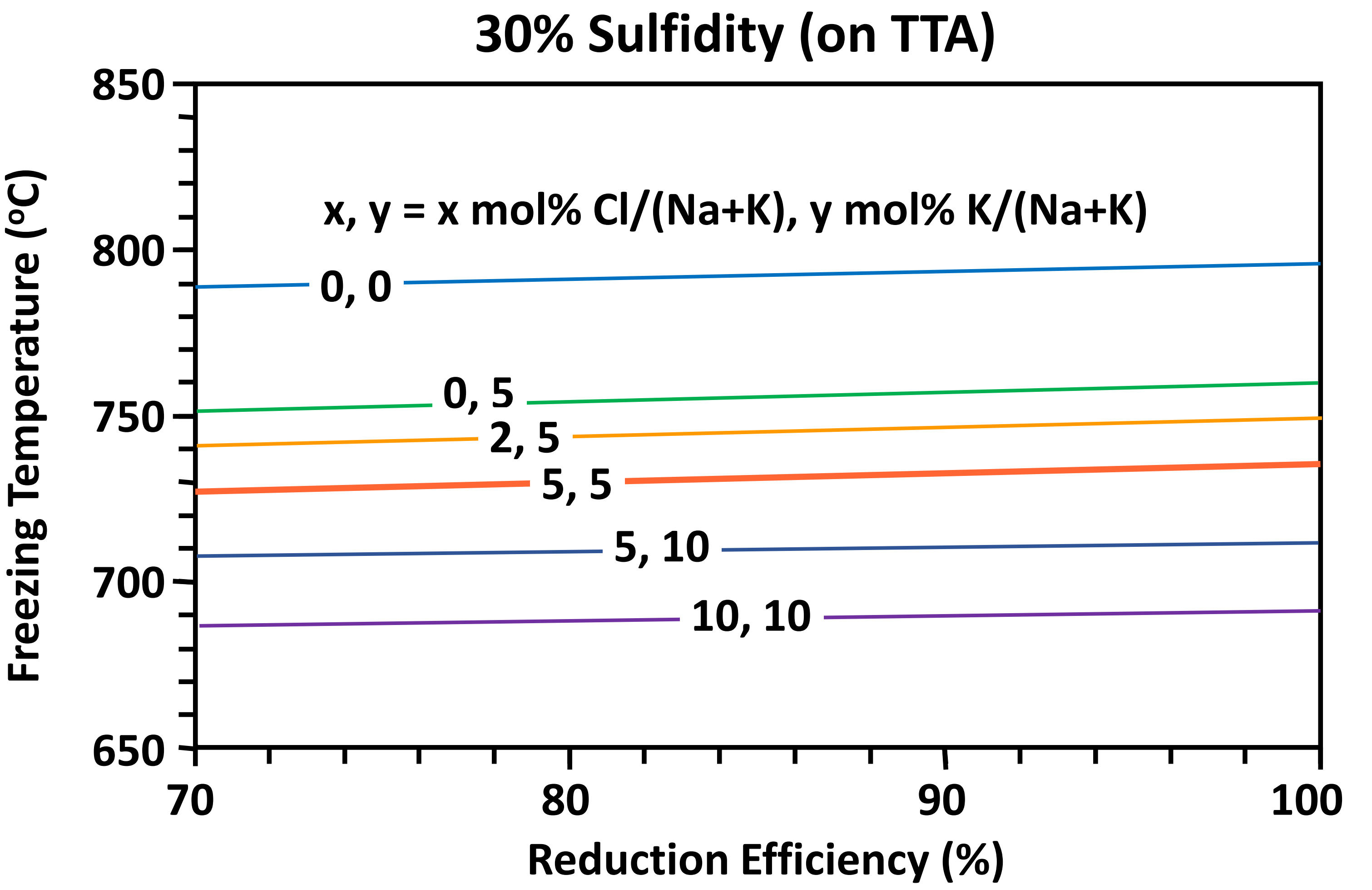
Chartrand, P. (2005)

Composition and Freezing Temperature of Smelt/ Fallen Deposit Mixture



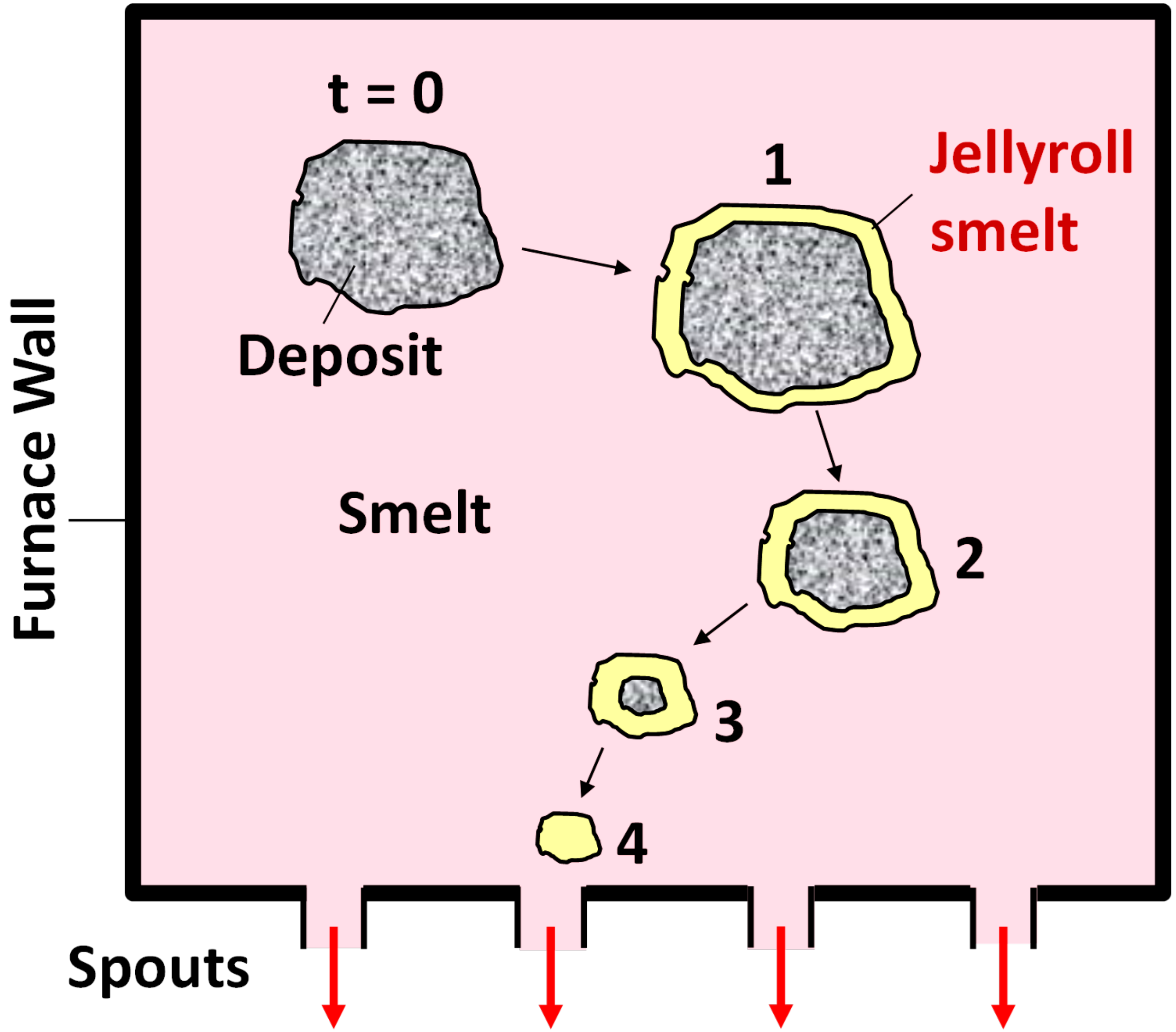
Chartrand, P. (2005)

Effect of Smelt Reduction (Sulfate Content) on Smelt Freezing Temperature/Viscosity



➔ **No significant effect!**

How Does a Fallen Deposit form Jellyroll Smelt?



Key Points

- Even for boilers operating at a reduction efficiency as low as 70%, the sulfate content in smelt has no/little impact on smelt freezing temperature, and hence on molten smelt viscosity.
- The perceived adverse effect of high sulfate content on smelt viscosity comes from the high sulfate content in deposits fallen from the upper furnace.

Key Points

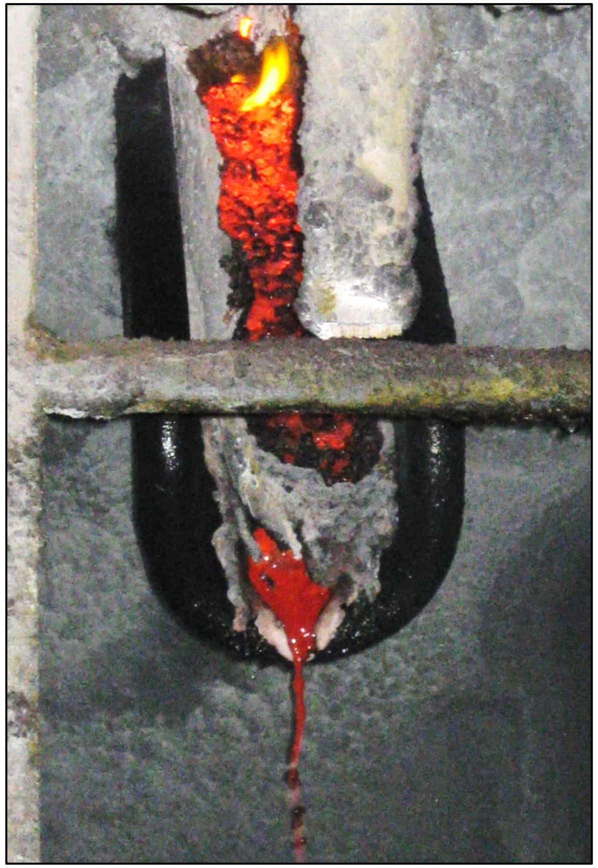
- Whether fallen deposits can form jellyroll smelt depends on whether they can melt and be well mixed with molten smelt by the time they reach smelt spouts;
- It is NOT the high sulfate content in smelt resulting from the low smelt reduction efficiency that makes molten smelt viscous;
- It is the incomplete melting of fallen deposits that leads to jellyroll smelt formation.

2. Interaction Between Highly Viscous (Jellyroll) Smelt and Water

Mill Experience with Jellyroll Smelt

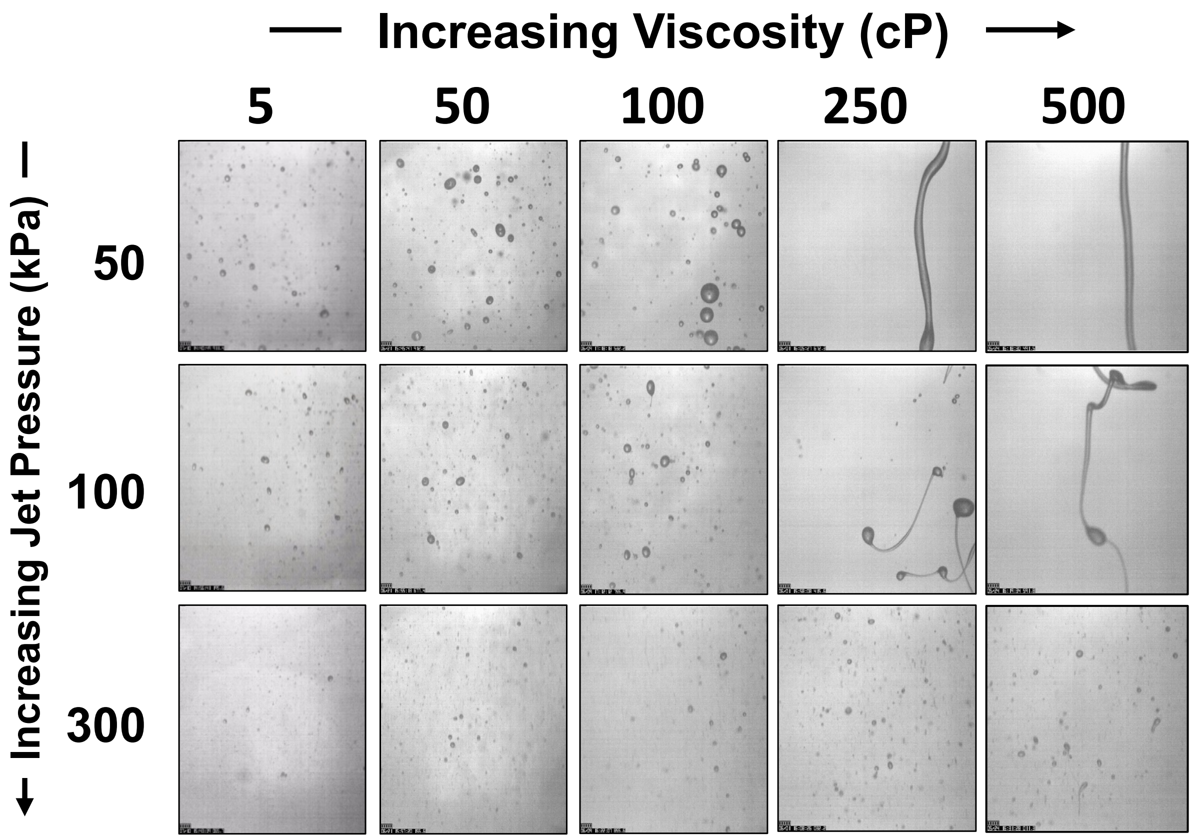
- Cannot be shattered readily
  - Enters the SDT in large lumps
- Makes loud noise
  - Jellyroll smelt clogs spout openings
  - Clogged spouts allow accumulation of a large amount of molten smelt behind them → Smelt runoff → Loud noise
- Questions are:
  - Can viscous jellyroll smelt be broken up by shatter jets?
  - How does it interact with water in the SDT?

Jellyroll Smelt Viscosity



- Simulated tests using corn syrup + sugar mixtures suggest that the viscosity of jellyroll smelt may be in the range of 10,000 – 100,000 cP

Shattering Viscous Fluids at a flow rate of 2.5 L/m



10,000 – 100,000

400 – 800 kPa
(60 – 120 psig)

Impossible to shatter?

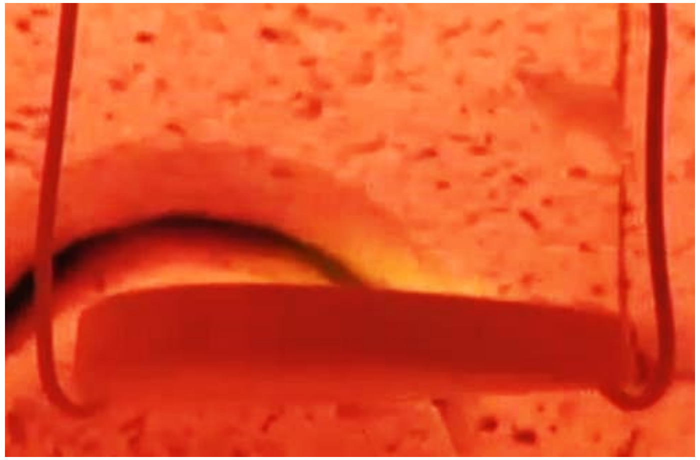
Taoxin Jiang, U of T (2018)

Jellyroll Smelt – Water Interaction

- 30^{+} experiments were carried out
- Experimental conditions
  - Sample size: 0.15 – 3 grams
  - Molten smelt produced by burning black liquor at 800^{o}C and 900^{o}C
  - Adding NaCl to black liquor to make smelt more fluid
  - Producing smelt that contains char (jellyroll smelt) or no char (normal smelt)
  - Dropping the sample into water at 15^{o}C - 80^{o}C
  - Videoing the interaction

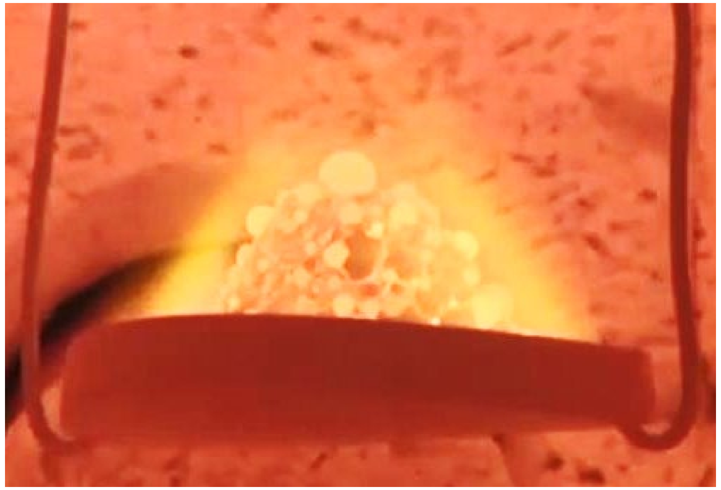
Black Liquor Burning on a Steel Tray

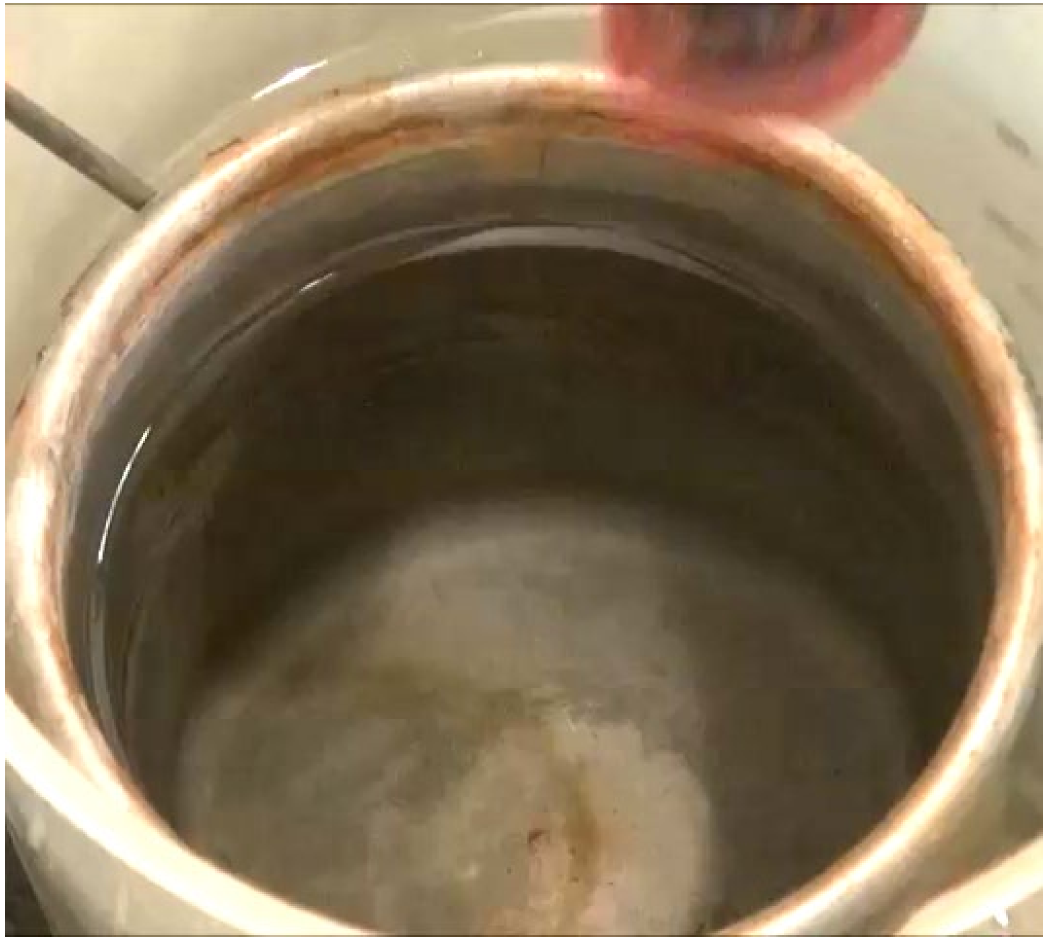
1.5 g sample, 800°C furnace, 75°C water, no char



Black Liquor Burning on a Steel Tray

1.5 g sample, 800ºC furnace, 75ºC water, with char





Black Liquor + 20 wt% NaCl

3 g sample, 900°C furnace; 80°C water

With char

No char

Key Points - 1

- **Jellyroll smelt formed by char-inclusion explodes or not, depending on the char amount, smelt temperature and smelt fluidity**
- **Char does not affect molten smelt-water interaction**
- **Jellyroll smelt with a large amount of char does not explode due to its lower temperature and smaller amount of smelt**
- **Jellyroll smelt formed by partial freezing or by fallen deposits does not explode due to its lower temperature and lower fluidity**

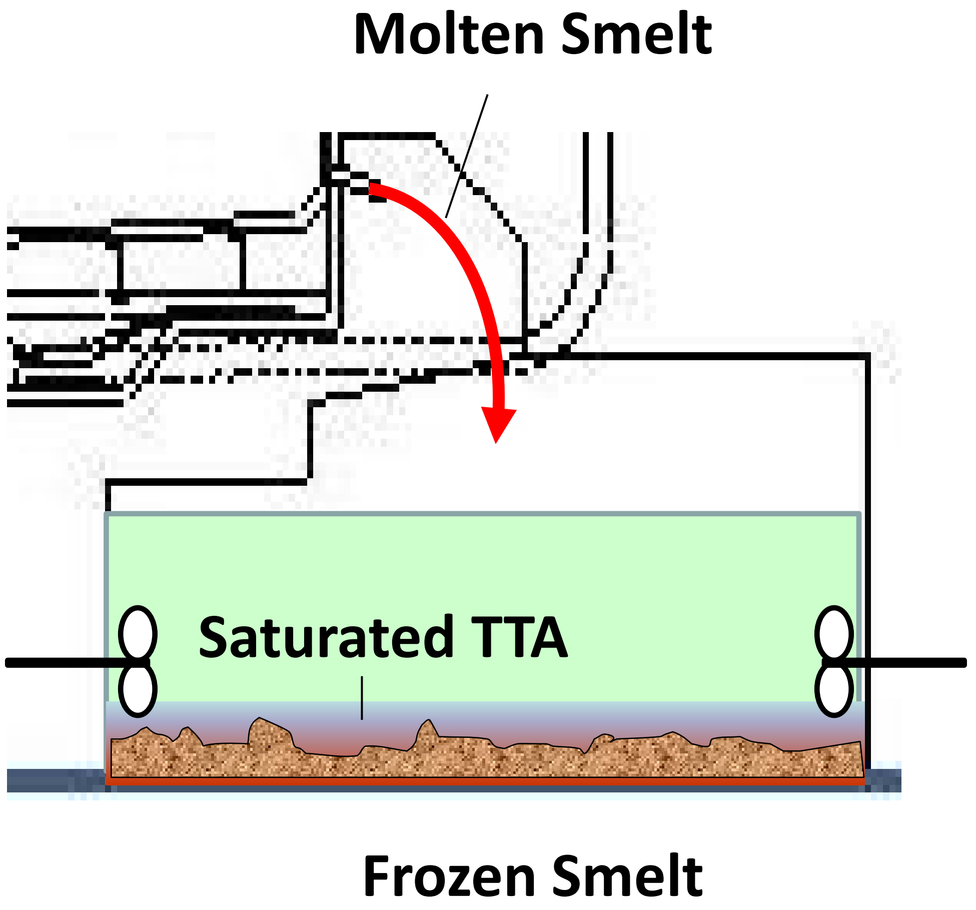
Key Points - 2

- Jellyroll smelt likely falls into the dissolving tank unshattered
  - It explodes or not depending on the characteristics of the molten smelt portion;
  - Char itself does not explode. It eventually falls apart and becomes dregs as smelt dissolves.
- Loud noise that accompanies a jellyroll smelt incident is more likely caused by the run-off of massive molten smelt accumulated behind the jellyroll smelt.

3. Dissolution Kinetics of Frozen Smelt

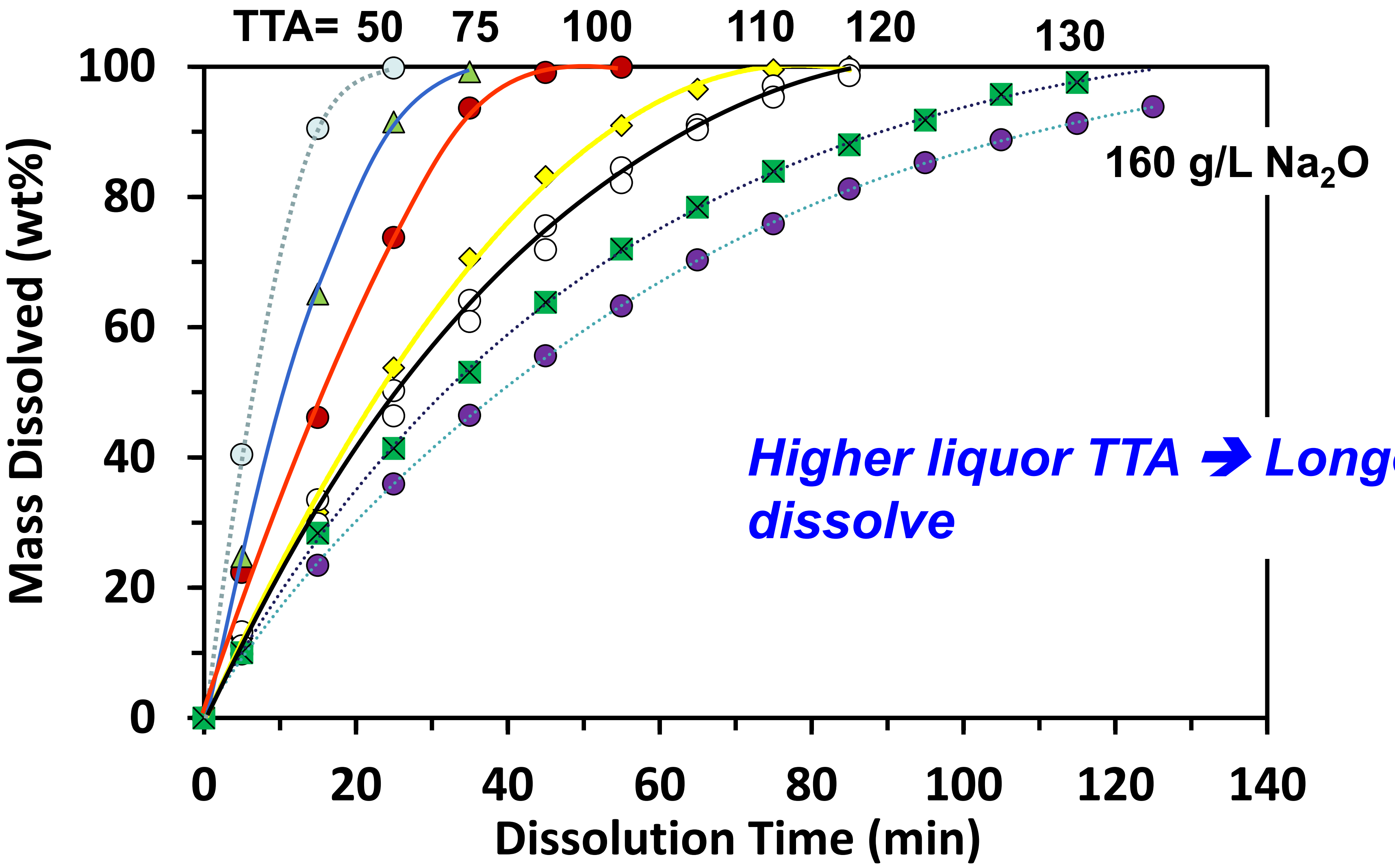
What Happens if Molten Smelt Enters the SDT Unexploded?

- It freezes, sinks and accumulates on the tank floor
- Frozen smelt does not dissolve readily
  - High liquor TTA near the tank bottom
  - Possible formation of hard Pirssonite scale
- What are the factors affecting the frozen smelt dissolution rate?



Effect of Liquor TTA

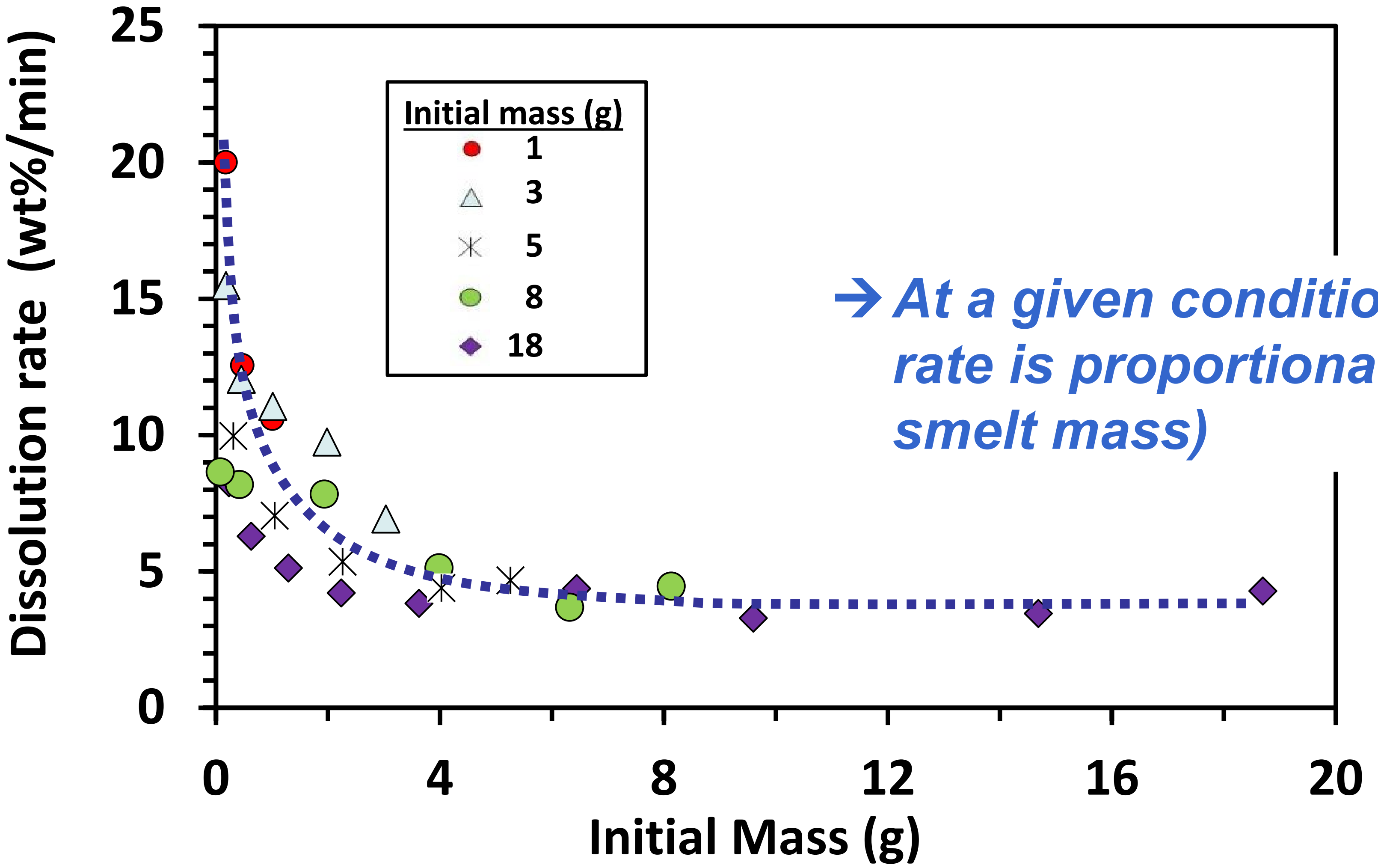
Initial weight = 8 g, Liquor temp. = 95°C, 150 rpm



Higher liquor TTA ➔ Longer time to dissolve

Dissolution Rate vs. Sample Initial Mass

95°C, TTA = 100 g/L Na_2O, 150 rpm



→ *At a given condition, dissolution rate is proportional to 1/(initial smelt mass)*

Key Points

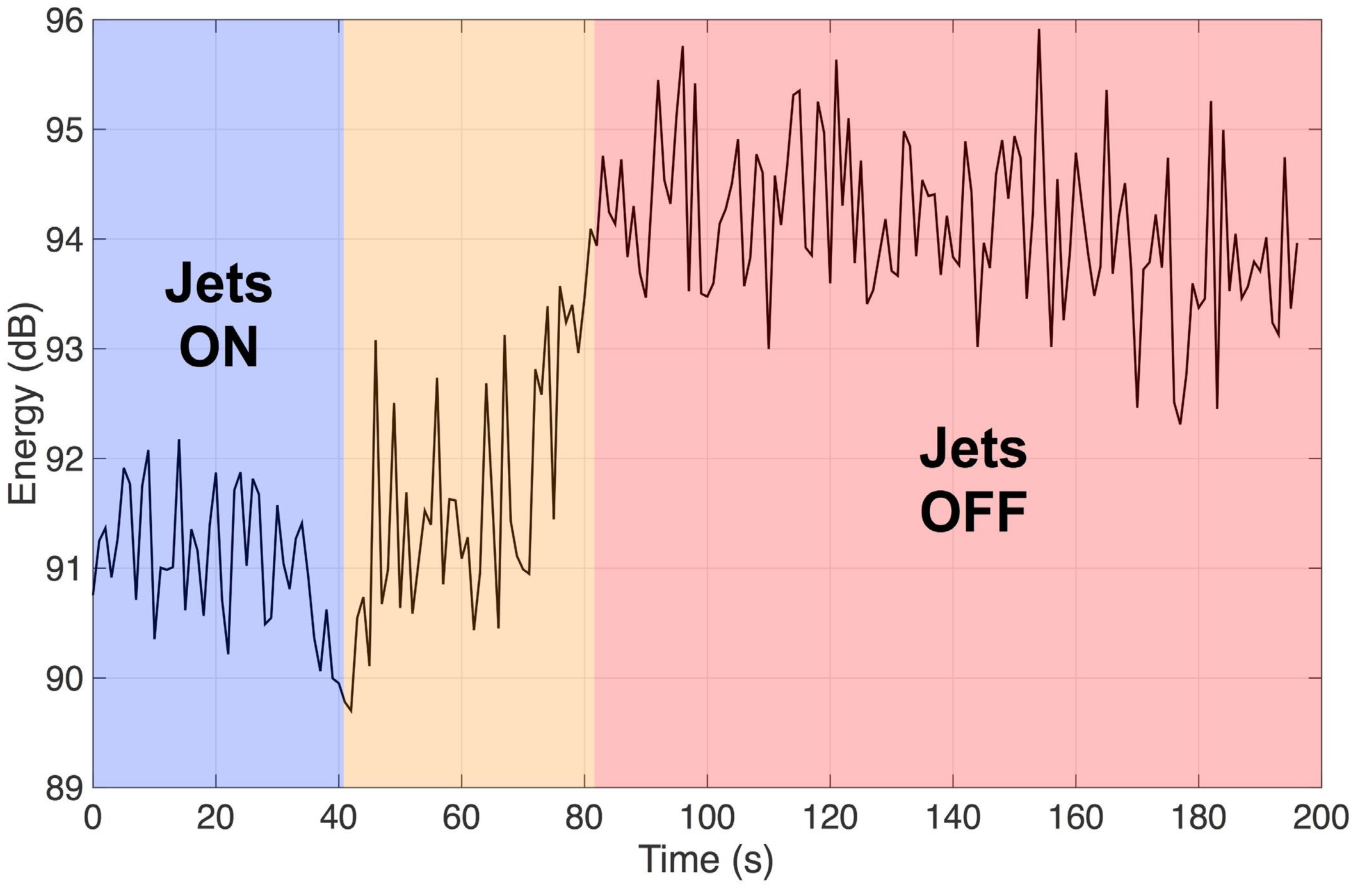
- **Frozen smelt is more soluble in green liquor with smaller smelt mass, lower liquor TTA, higher liquor temperature**
- **Dissolution rate is proportional to 1/(initial smelt mass)**
- **Frozen smelt fragments dissolve independently of one another**
- **The more the number of fragments, the more quickly frozen smelt can dissolve if the liquor is not saturated → Importance of well mixing**

4. Development of the SDT Acoustic Model

Questions

- How is noise generated in the SDT?
- Can noise be used to monitor/control SDT operation?
- Development of a mathematical algorithm for tank noise monitoring (Brian Wang – PhD candidate)

Sound Intensity Measurements

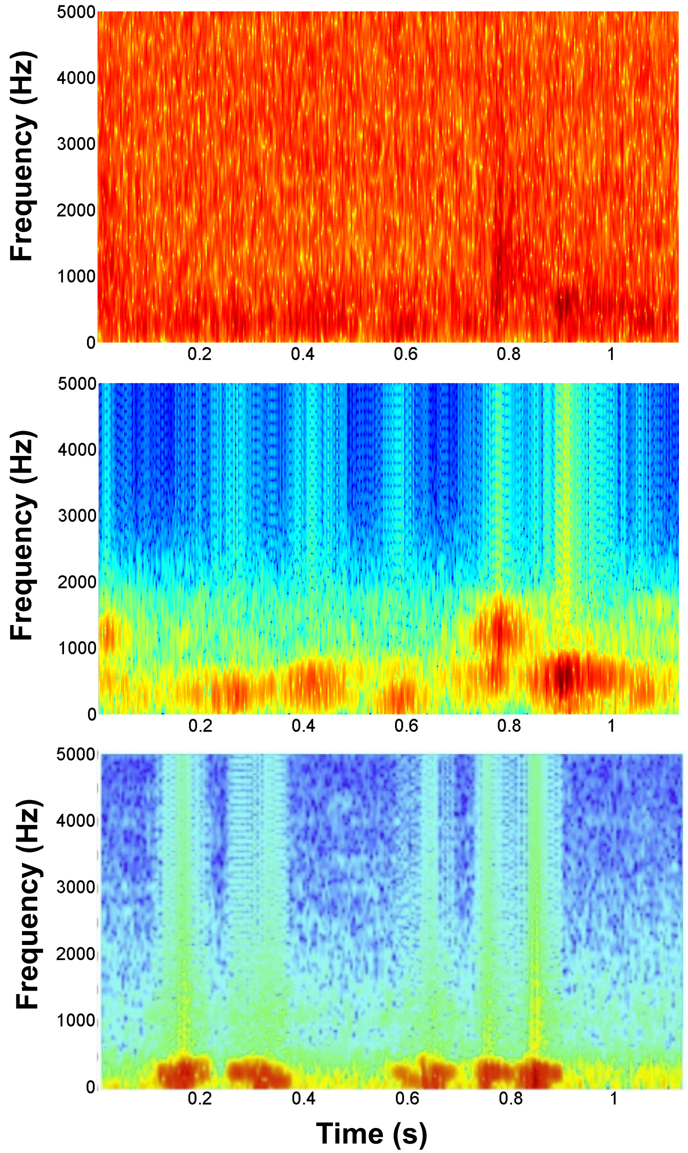


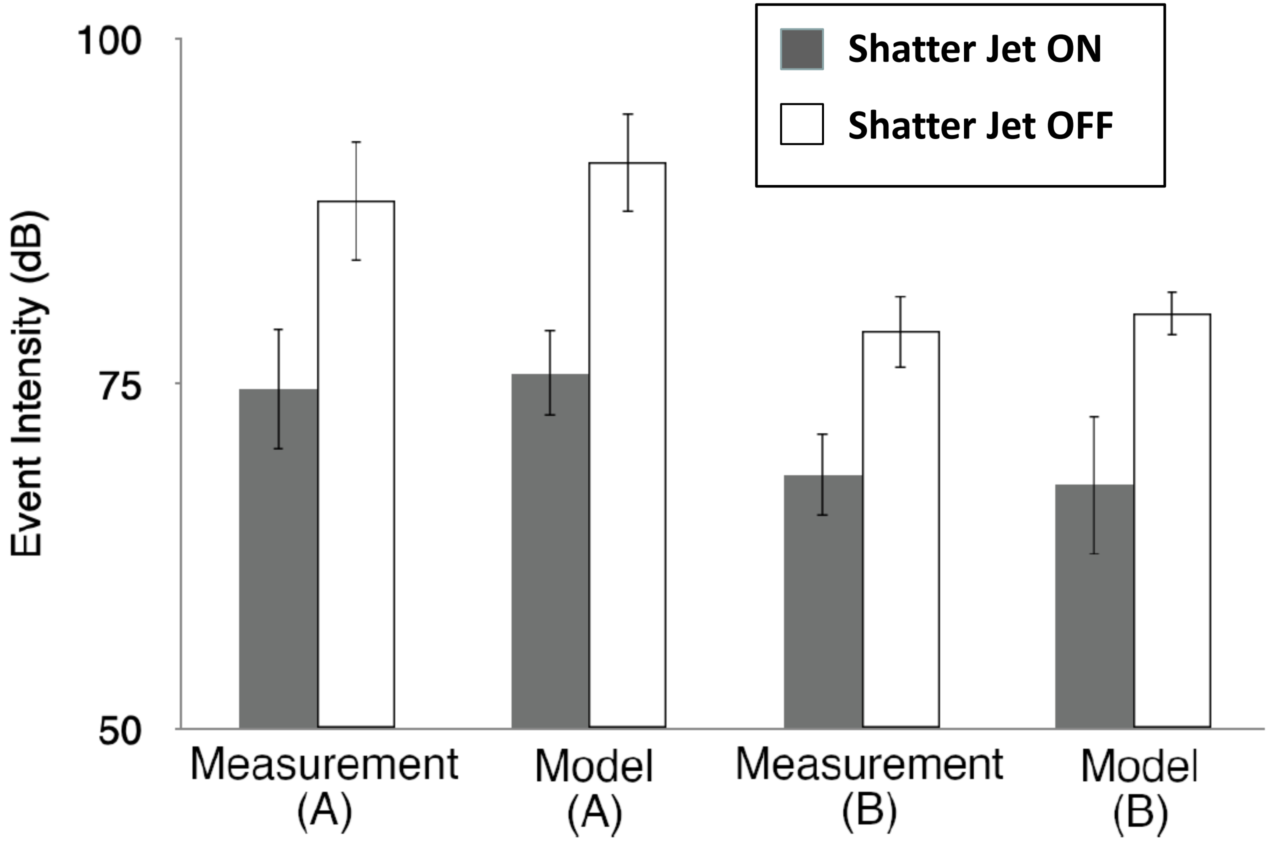
Processing SDT Acoustic Signals

Raw Data

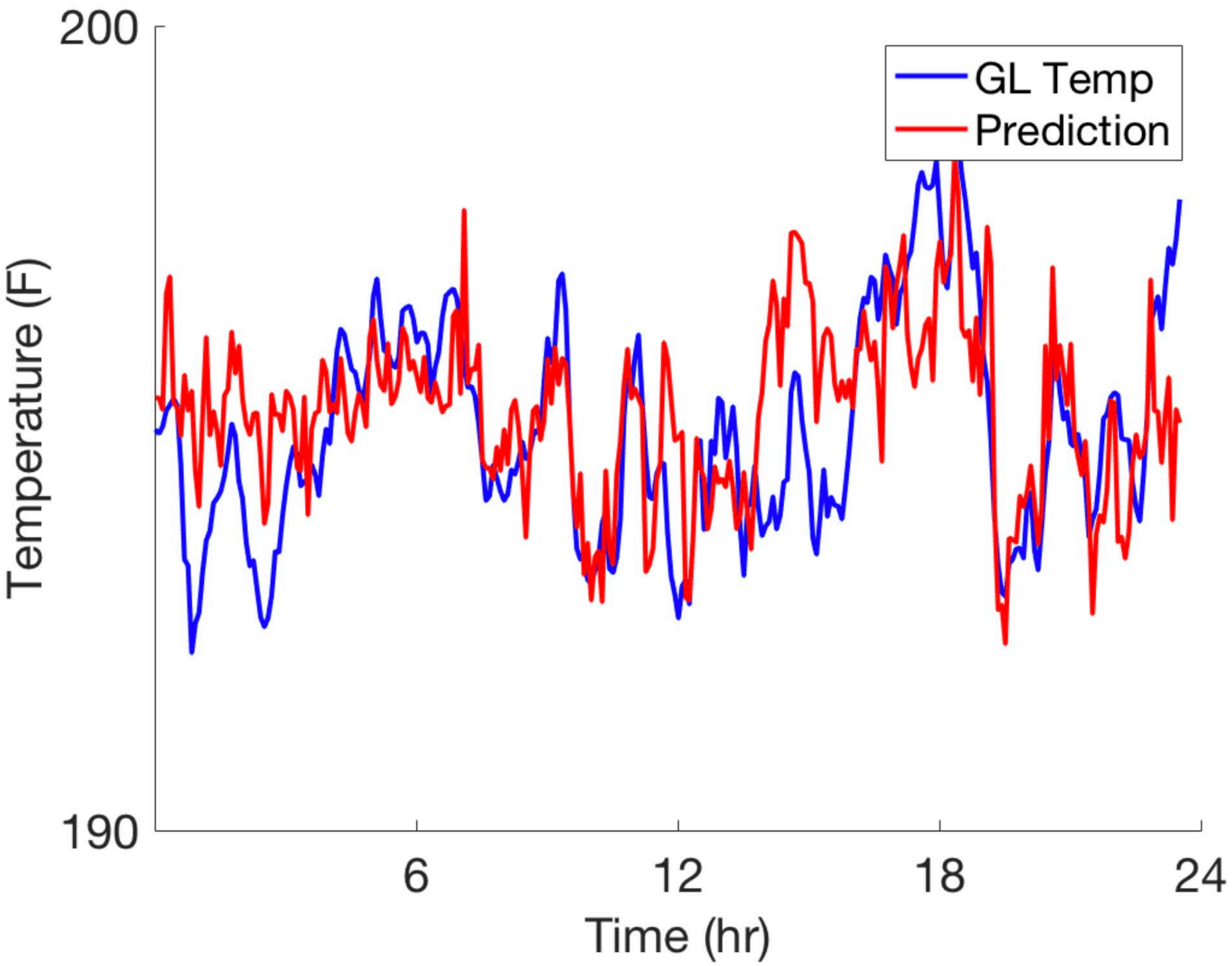
De-noised

Model Prediction



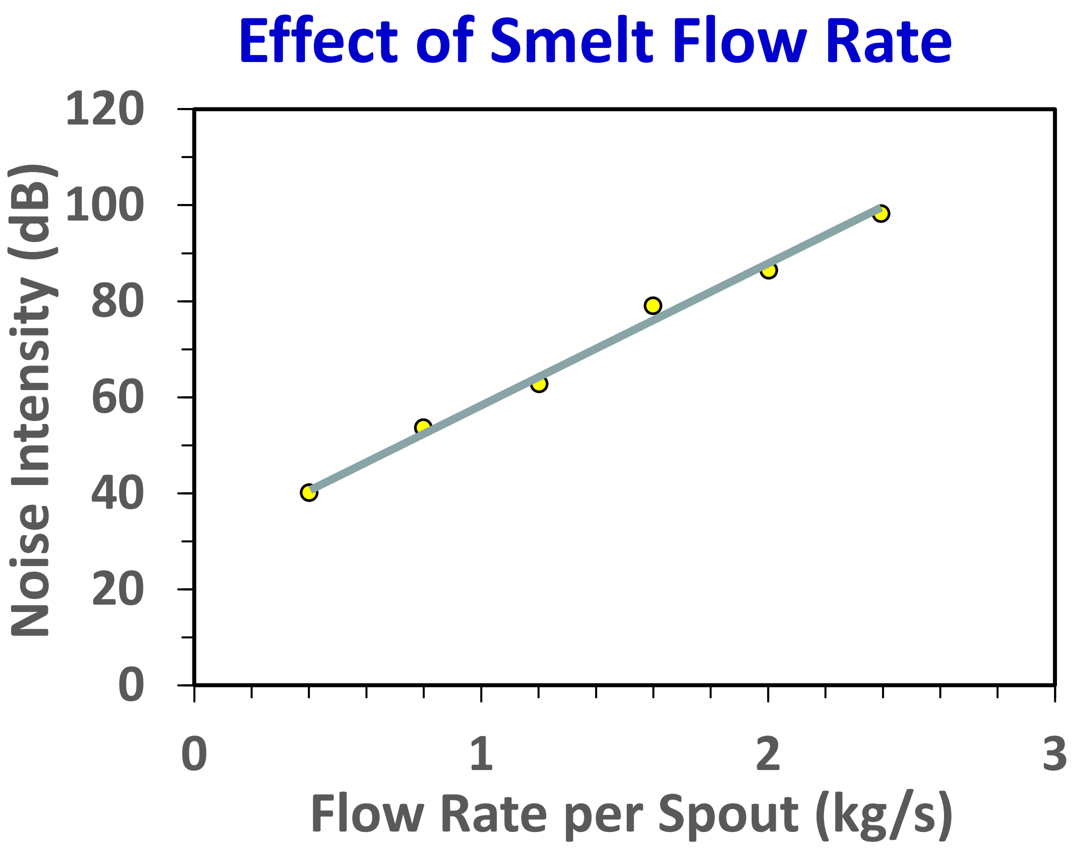


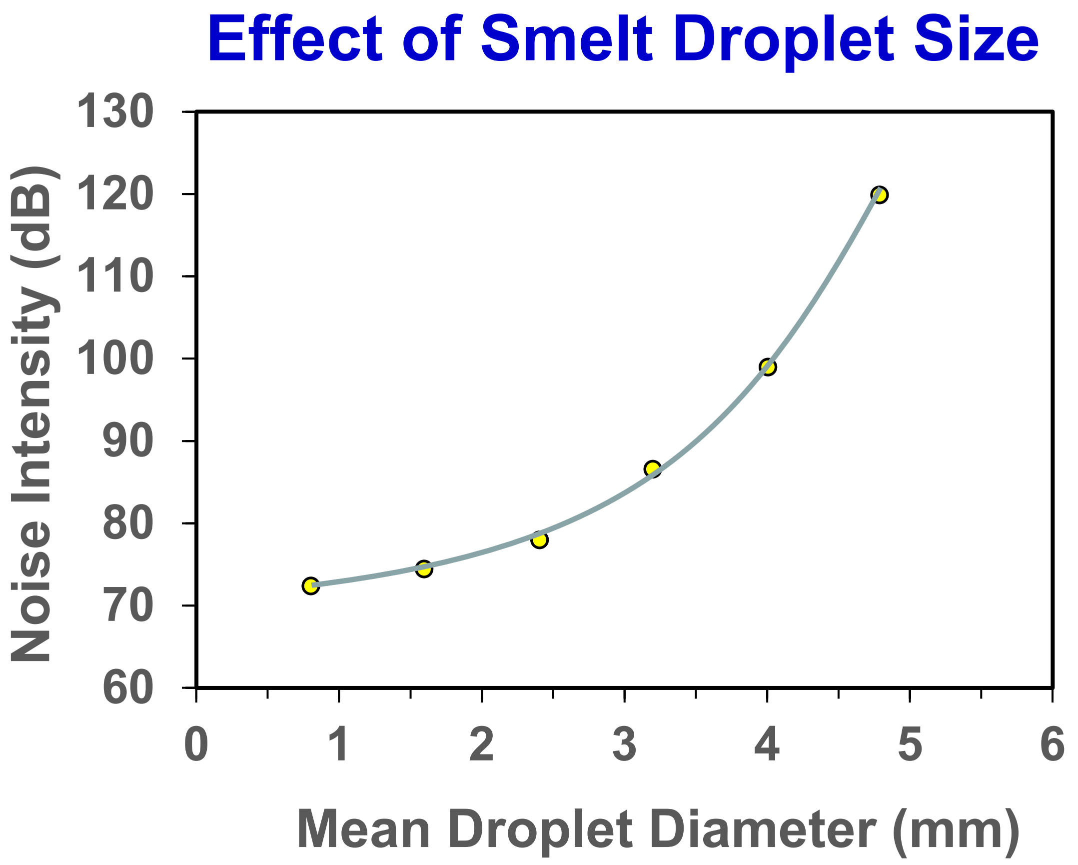
Predicting Green Liquor Temperature from Sound



- **Louder noise ➔More smelt ➔ high liquor temperature**

Parametric Studies Using the Acoustic Model





Key Points

- **An acoustic model has been developed and tested;**
- **A change in acoustic level can be related to changes in SDT operation**
- **Parametric studies using the model confirm the importance of smelt flow rate and smelt shattering**

Acknowledgements

AF&PA Recovery Boiler R&D Committee and Members of University of Toronto Research Consortium

ANDRITZ
ARAUCO
B&W thebabcock&wilcoxcompany
Canadian Kraft Paper
CENIBRA

CLYDE BERGEMANN Power Group
cmpc
ERCO Worldwide
FIT NIR
FPInnovations
Georgia-Pacific

INTERNATIONAL PAPER
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rethink. storaenso

SUZANO PAPEL E CELULOSE
Valmet
WestRock
NSERC CRSNG

PressureWave+ Technology Overview

Agenda's topics

Topic	Slides
Technology Introduction	4 - 7
PressureWave+ Cleaning Overview	9 - 13
PressureWave+ Safety	15 - 16
PW+ FAQs	18
Cleaning Examples	20+

PW+ Introduction

PressureWave+ with Bang&Clean Technologies AG Global Footprint

Bang&Clean Technologies

Patented technology, introduced in 2001, by Bang&Clean Technologies AG from Switzerland, executed by General Electric

- Bang&Clean, GE, and other partners have executed more than 20,000 cleanings worldwide, in various industries.
- GE cleans globally and has planned and preformed successful cleanings in:
  - Indonesia, Japan, Malaysia, Vietnam, Pakistan, Argentina, Chile, Dominican Republic, Mexico, Puerto Rico, Bahrain, Canada, and USA

Verified Cleaning Applications

Online

- **Black Liquor Recovery Boilers (exclusive license)**
- Utility Power Boilers
- **Electrostatic Precipitators**
- Circulating Fluidized Bed Boilers
- Waste to Energy Boilers
- **Bark Boilers**

Offline

- Heat Recovery Steam Generator (HRSG)
- Utility Power Boilers
- **Electrostatic Precipitators**
- Circulating Fluidized Bed Boilers
- Waste to Energy Boilers
- Silos and Storage

“

Correspondingly, the result of the investigation is that, in the considered realistic load cases, a permanent deformation due to the detonation can be excluded…

zh aw School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

Christian Jenni, Prof. Dr. Markus Weber Sutter
ZHAW Institute of Energy Systems and Fluid Engineering (IEFE)

Customer Challenges

Buildup and blockages causing ΔP and temperature challenges caused by:

Corrosion/Rust formation

- Offline/online corrosives/corrosion products

Deposits in flue gas

- e.g. Sulfur, salts

Slag & Ash

- Combustion by-products

Debris

- Insulation

Clinkers

PressureWave+ Tooling

Equipment and Consumables

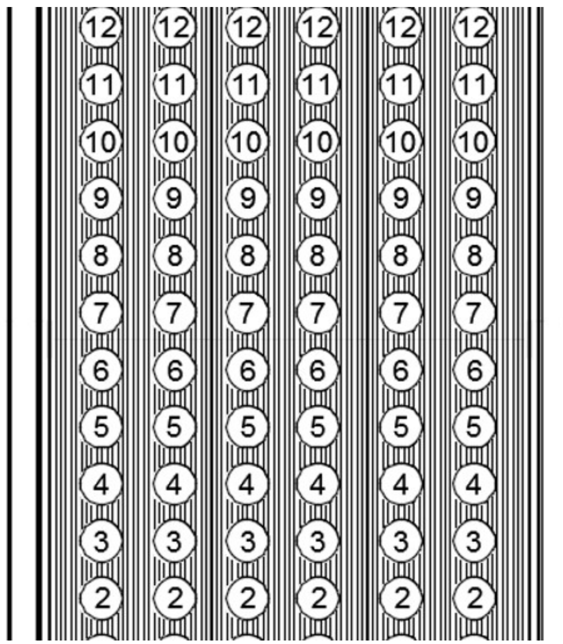
- PW+ Proprietary:
  - Dosing station
  - Lance
  - Air and Gas lines
  - Regulator system
- Rigging and positioning cables
- Compressed Gas Cylinders
- PW+ bags

PW+ Cleaning Overview

PW+ Cleaning Overview

1st: Determining Access

2nd: Determining the Grid



3rd: Clean

PW+ Cleaning Strategy

1st: Determining Access

Option 1

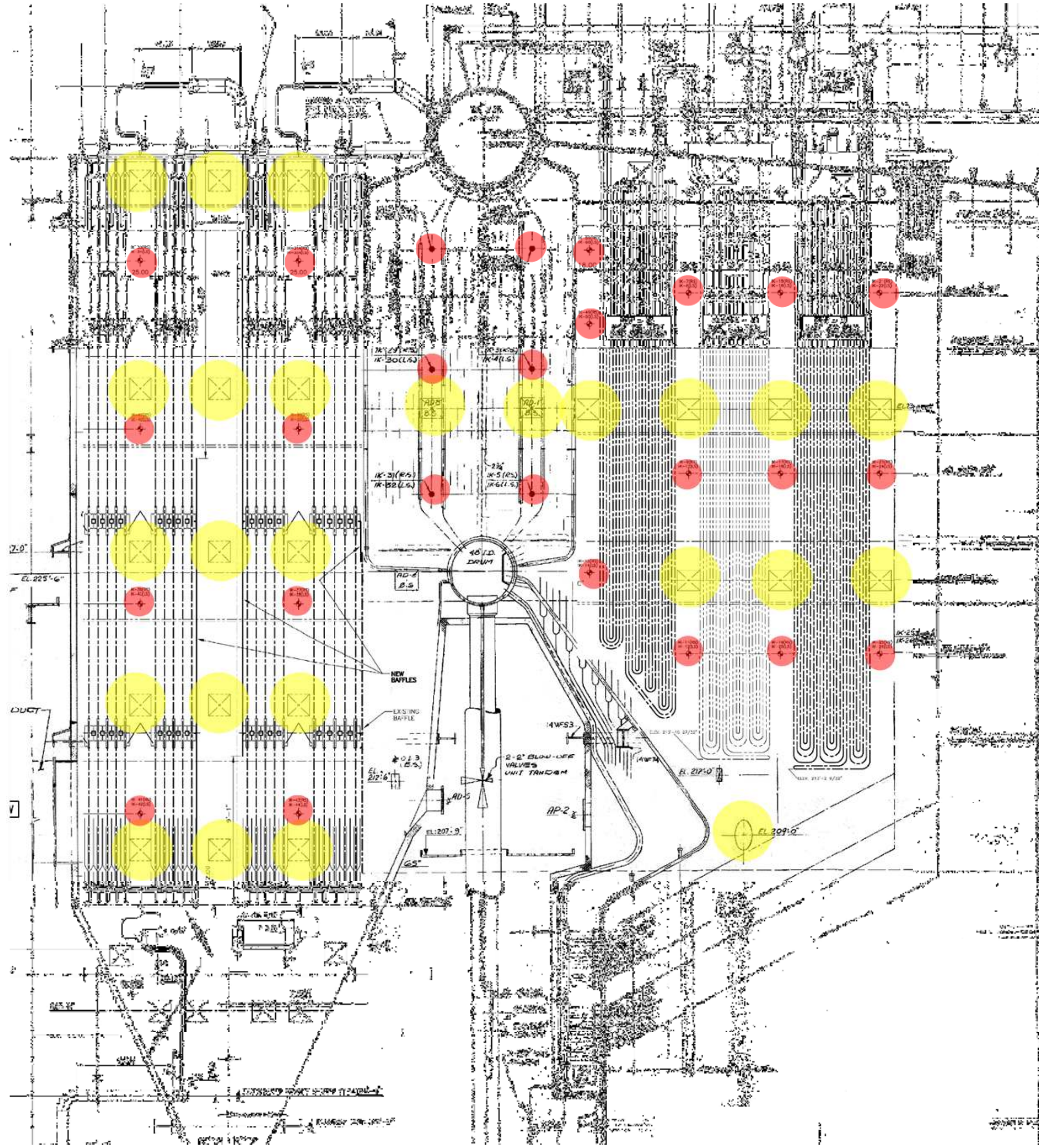
Blower openings

Tooling is inserted through existing blower openings.
The blowers may need to be moved.

OPTION 2

Access Doors

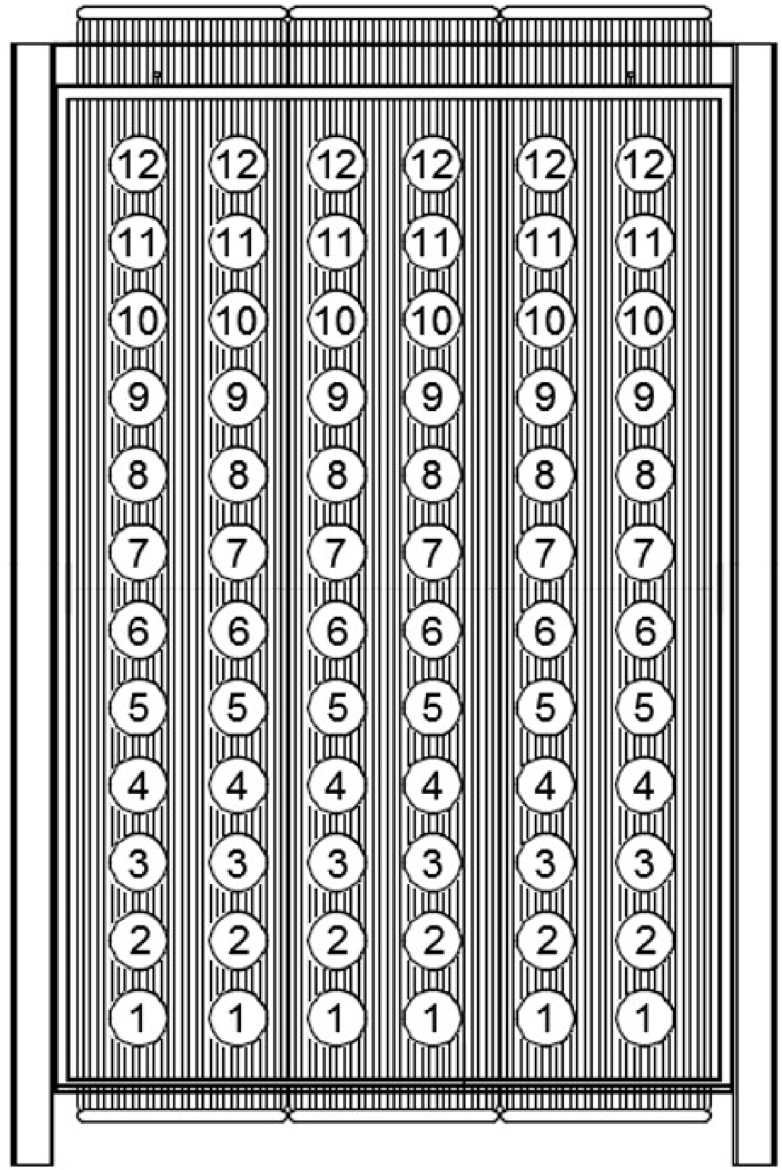
Doors opened and tooling inserted with sufficient draft.



PW+ Cleaning Strategy

2nd: Determining the Grid

- Using customer supplied information and walkdowns, a cleaning plan is drafted.
- Cleaning performed in a methodical grid pattern, typically starting at the bottom.
- 3-7 shots occur every 5'-6' vertically and horizontally
- Shots occur every 2-4 minutes on average
- Lance and PW+ bags are inserted through doors, ports, and/ holes and adjusted directly or through rigging



PressureWave+
Online Application

Cleaning Steps:

1. Equipment is set to allow safe cleaning
2. Technicians prepare the bag and lance
3. Align lance and team for the bang
4. Once the tools and team are in alignment:
    1. The bag is inserted
    2. The gases are mixed and dosed
    3. The gases are combusted
5. The lance is removed while the lance is undergoing a purge and cooling cycle

PressureWave+
Online Application

Cleaning Steps:

1. Equipment is set to allow safe cleaning
2. Technicians prepare the bag and lance
3. Align lance and team for the bang
4. Once the tools and team are in alignment:
    1. The bag is inserted
    2. The gases are mixed and dosed
    3. The gases are combusted
5. The lance is removed while the lance is undergoing a purge and cooling cycle

PW+ Safety

Is it safe?
Top Safety Points

#1 Hazard Elimination

1. Two new lance options for purge and cooling between PW's.
2. Internal and external studies have been done to show there is no risk of damage to pressure parts

#2 Substitutions

Controlling Energies

- NO transfer or storage of explosives
- Pressure waves generated by the combustion of gas typically propagate at much lower speeds than pressure waves generated by explosives.

#3 Engineering Controls

Isolated Gas's and Hazards

- Numerous barriers of shut-off and non-return valves prevent gas leakage.

#4 Administrative

Isolated Gas's and Hazards

- The combustible gas mixture is prepared only moments before ignition
- 2-step process controlled by 1 qualified technician
  1. Dosing station fills internal tanks
  2. Dosing station fills bags, horn sounds, gas ignition

Cleaning Procedures

Process Safety

- Every project has an associated method statement and Job Hazard Assessment completed
- All employees are trained on Bang & Clean process and receive certificates
- All employees are required to train and work to GE's stringent EHS and OSHA policies
- All employees are placed on Federal ATF Explosives License as Employee Possessors
- ONE employee is responsible for placing the bag and starting the shot sequence

Equipment Safety

- Dosing station has several non-return valves and flashback arrestors to prevent any ignited gas from returning to the dosing station
- Manual two-step process required to complete each shot.
  1. Dosing station fills internal tanks
  2. Dosing station fills bags, horn sounds, gas ignition
- Dosing station uses a standard spark plug for ignition, no blasting cap
- Air is used to purge the lines after ignition occurs

PW+ FAQs

Frequently Asked Questions

Damage to Equipment

Internal and external studies have been done to show there is no risk of damage to pressure parts. Care must be taken around soft expansion joints, sensitive equipment, and SCR catalyst

Timing

Cleaning times depend on:

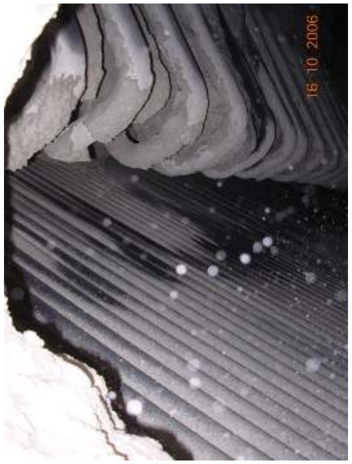
- Cooling/purge time
- Access
- Size of the equipment
- Unit dirtiness

Noise Levels

Distance Outside	Best Case	Worst Case
0 ft	90 dB	110 dB
500 ft	63 dB	88 dB
1 km (1/2 mi)	49 dB	74 dB

Cleaning Examples

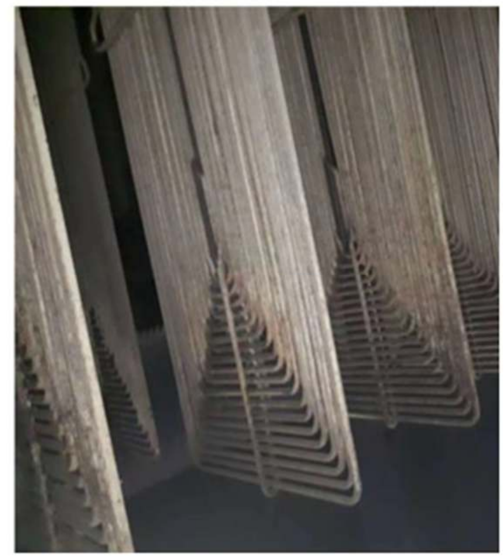
PresssureWave+ Cleaning in Recovery Units



Pendants:

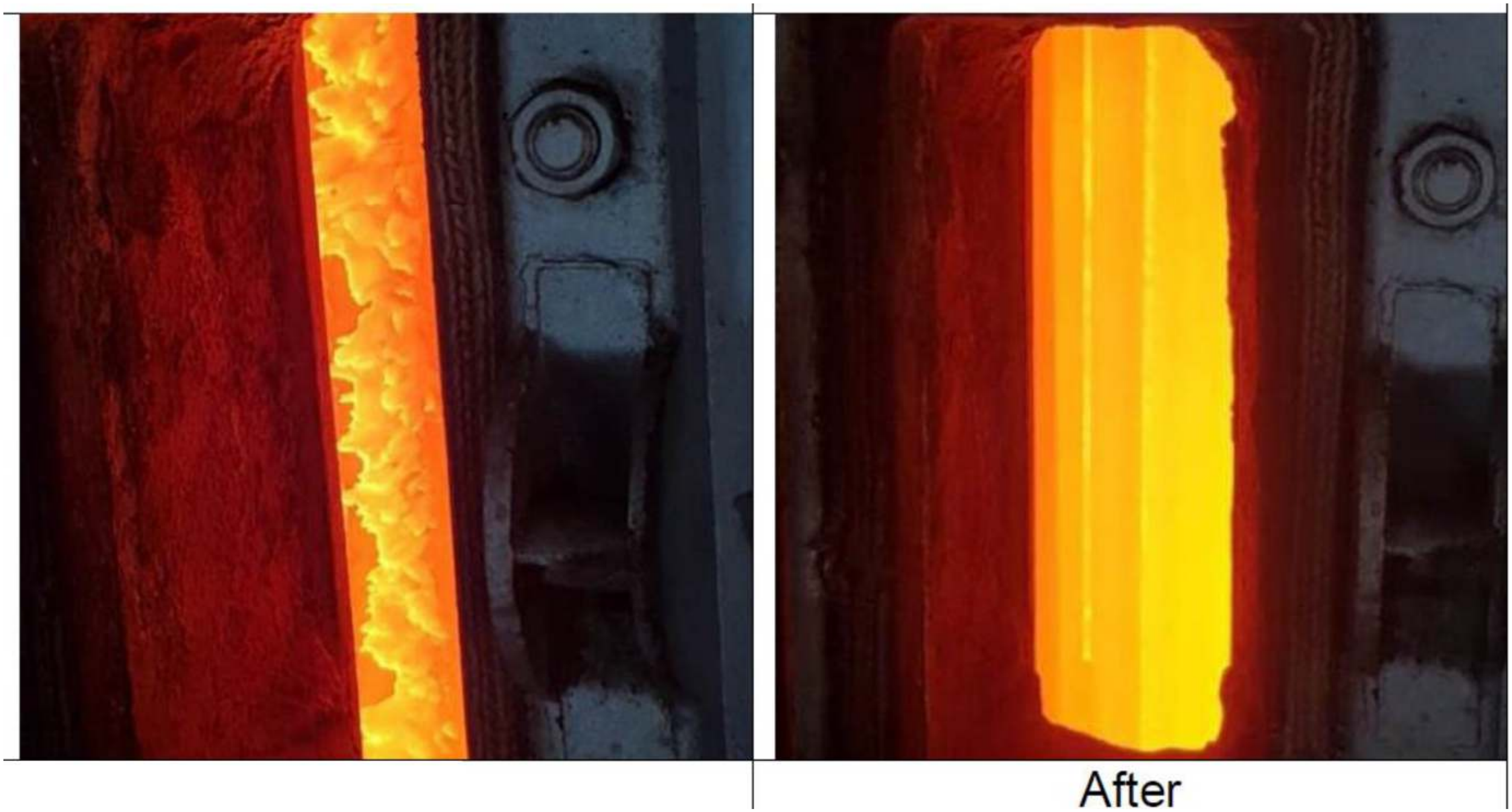
Furnace cleaning on SH with fouling during cooling down process

Furnace / SH after cleaning

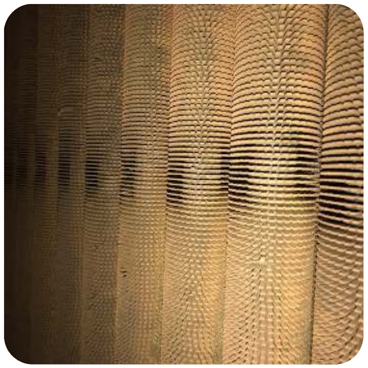
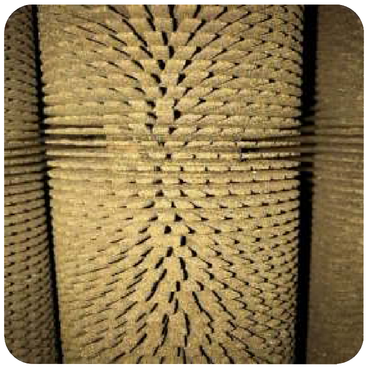
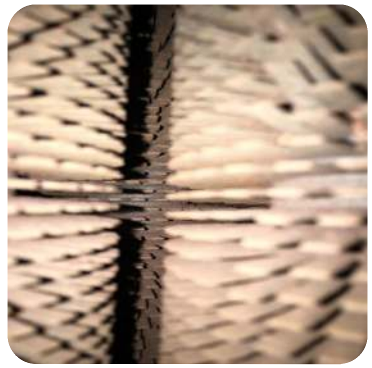


Examples:

Pendant Reheater:



HRSG:





GORE-TEX
BRAND

MULTI HAZARD GORE-TEX PYRAD® GARMENTS

JIM ELLIS & PAUL DACEY
W. L GORE & ASSOCIATES
TECHNICAL
ORIENTED
FABRICS
Feb 2nd, 2022

TODAY’S PRESENTATION IS ABOUT MULTI-HAZARD PPE

GOING FURTHER, TOGETHER.

Single Garment Providing Protection from Multiple Mill Hazards

Liquid Chemical Splash Protection

Flame Retardant Flash Fire Protection

Arc Flash Protection

Human Comfort Factors

Light Weight

Breathable

Quick Redry – Fast Recovery

GORE-TEX BRAND
GOING FURTHER, TOGETHER.

HAZARDS OF LIQUID CHEMICAL SPLASH

Objective for Chemical Splash Safety PPE

- Workers and safety managers in the Pulp and Paper Industry seek confidence in liquid chemical splash protection with rated / certified products to:
  - Reduce costly injuries due to the gaps in chemical and thermal protection.
  - Reduce productivity loss / downtime (heat stress).
  - Reduce high total cost of ownership for existing PPE.
  - Increase employee´s personal safety.

QUALIFICATION OF PPE FOR MULTI HAZARD

ENSURING FITNESS FOR USE

GOING FURTHER, TOGETHER.

Gore commits to deliver products that meet our customer´s expectation and are fit to their intended use:

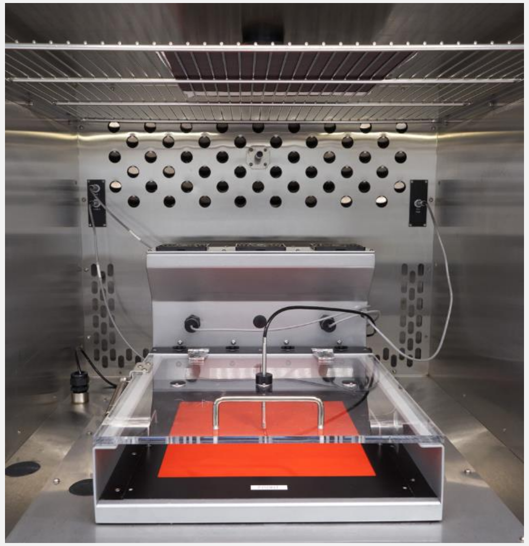
- Delivering products that meet requirement according to standards.
- Understanding material science, final product end-use and end-user needs.

Arc testing

PYROMAN™

Chemical penetration

Sweating hot plate



Thermal comfort

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GOING FURTHER, TOGETHER.

MARKET EXPLORATION JOURNEY

Pulp and paper market exploration

In-depth interviews with end-users

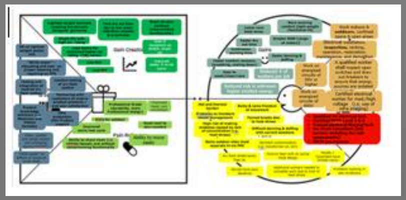
Multiple departments at several paper mills: chip screens, digesters, washers, evaporators, Bark Pile, Causticizing area and Recovery boiler.

Source of interviews:

Associations, BLRBAC & AFPA

Key Objectives:

Find the safety problem the mills are the most compelled to solve and develop a solution for it




GORE-TEX
BRAND
THE SCIENCE
BEHIND
MULTI HAZARD
GORE-TEX PYRAD®
GARMENTS

MULTI HAZARD GORE-TEX PYRAD® GARMENTS TECHNOLOGY

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GOING FURTHER, TOGETHER.

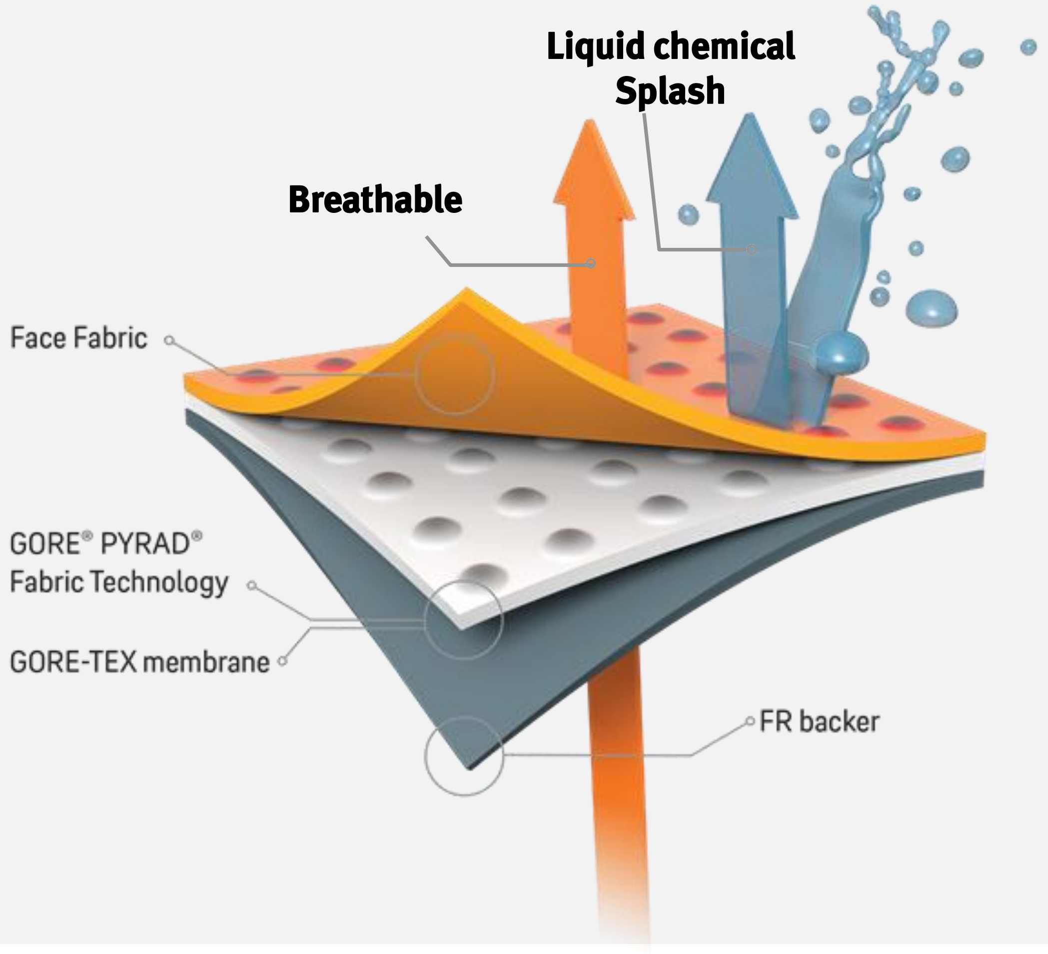
3 layers laminated into 1 ply

Polyester face fabric: easiness to dye into different colors (including Hi Vis), quick drying, tensile strength, and excellent abrasion resistance.

PYRAD® Fabric Technology: A self-extinguishing technology (countless reactive dots) that adds inherent and durable heat, flame and arc resistant properties.

GORE-TEX ePTFE membrane: strong, breathable, thermally stable and liquid entry penetration resistance at extremely light weight and thickness.

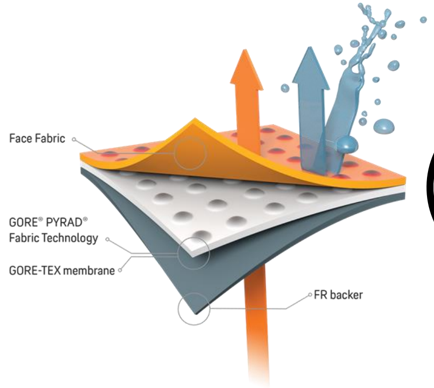
FR backer fabric: adds thermal stability, reduce burn caused by heat transfer and contributes to optimize the wearing comfort.



HOW IT WORKS: MULTI HAZARD GORE-TEX PYRAD® FABRIC

GOING FURTHER, TOGETHER.

Liquid Chemical Splash Protection

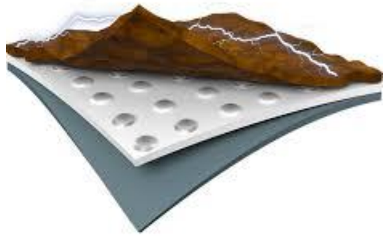


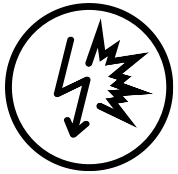
Tested against Several liquid chemicals

Flame Retardant Flash Fire Protection

Less than 40% 2nd degree predicted body burn at 3s exposure

Arc Flash Protection





Arc rating ATPV > 25 cal/cm²

The fabric prevents liquid chemicals from penetrating while allowing the perspiration to evaporate through the chemical barrier to the outside.

The fabric rapidly reacts causing the dots to expand and form a stable insulating protective shell of carbonaceous char with the face fabric (without melting or dripping) blocking the heat transfer to skin, stopping flame propagation, and blocking heat flow form the thermal hazards.

PERFORMANCE AND FITNESS FOR USE

CERTIFIED CHEMICAL SPLASH PROTECTION

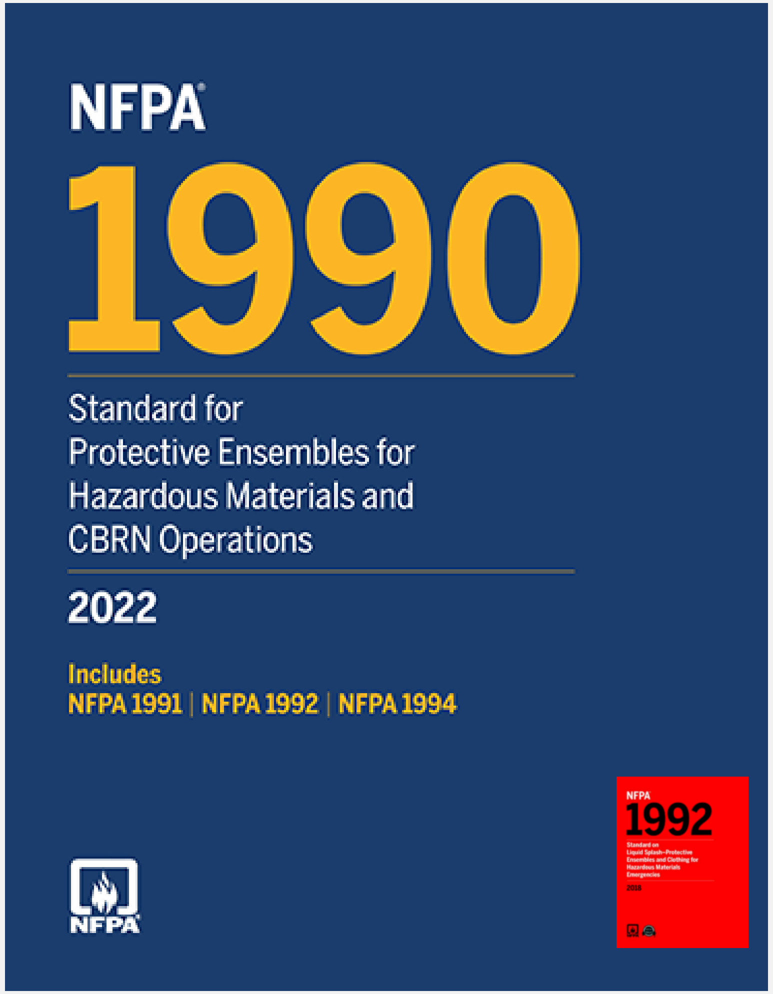
GOING FURTHER, TOGETHER.

The NFPA 1990 Standard addresses the entire liquid chemical suit. It sets minimum levels of performance for protection provided by the overall ensemble, garment material, seams, closures, and other components.

- Durable and robust resistance to **chemical penetration** is critical to all components , including the design of the chemical protective suit.

Multi Hazard GORE-TEX PYRAD® garments

- Tested and certified, exceeds the minimum performance requirements of NFPA 1992/1990 standards. Including an additional broad range of chemicals and specific chemical mixtures.
- Garments can be safely washed without compromising chemical protection.

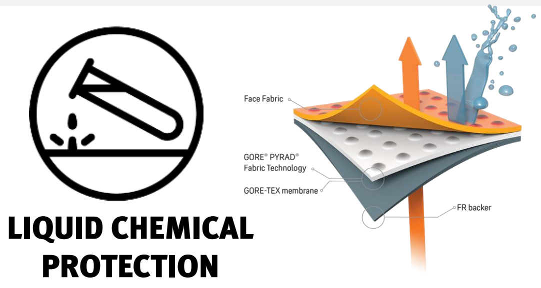


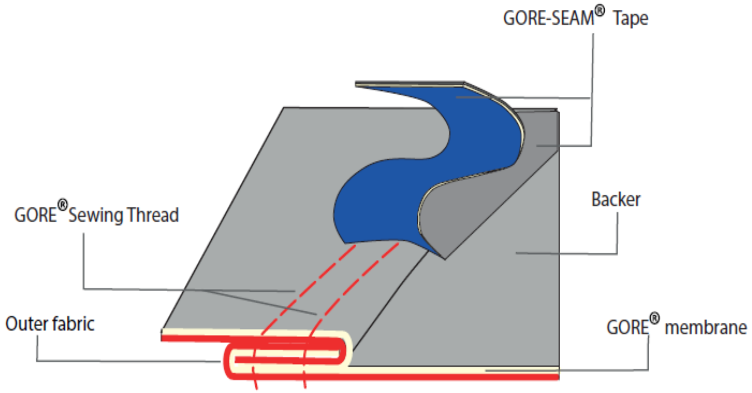
MULTI HAZARD GORE-TEX PYRAD® GARMENTS

GOING FURTHER, TOGETHER.

Fully seamed garments with high manufacturing standards:

- Utilize a proprietary materials to ensure the seams do not fail under harsh operating conditions.
- **GORE-SEAM® Tape** – To offers robust chemical resistance against liquid penetration and to ensure suits maintain integrity.
- **GORE® TENARA® SEWING THREAD -** Highly thermally stable and chemical inert that prevents wicking of chemicals that may cause diminished integrity of the seams over time or in certain operating conditions.





ENSURING OUR PRODUCTS PERFORM RIGHT EVERY TIME

GOING FURTHER, TOGETHER.

Gore Certified Factories must meet stringent quality requirements

The Liquid-proofness (Suter) test determines liquid pressure resistance of chemical resistant materials

Applied pressure for GORE-TEX laminates is 1 bar (compared to 0,13 bar as requested by standard EN 343 for waterproof clothes)

Some garment manufacturers claim ASTM F903 chemical splash testing but …

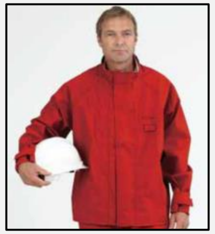
… only test the laminate and not the garments

"Do what we say they will do" The first time and every time

CAUTION: ONLY fully seam sealed garments can provide 100% chemical splash protection

Fully seamed sealed garment

Sewn using Gore TENARA monofilament thread



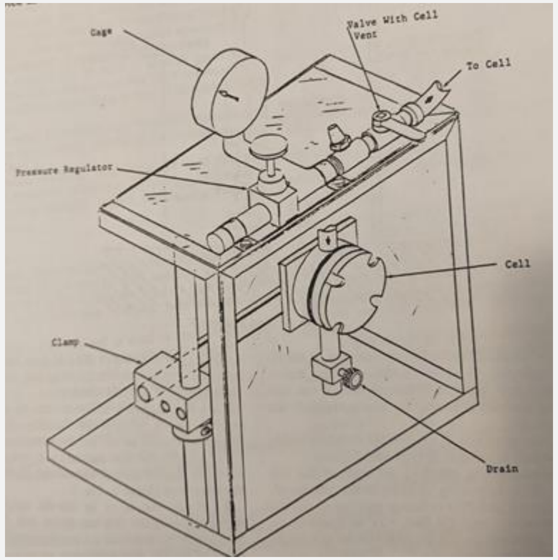
Whole garment integrity with Gore quality standard

FITNESS FOR USE TESTING: LIQUID CHEMICAL SPLASH

GORE-TEX BRAND
GOING FURTHER, TOGETHER.

Test Method for Liquid Chemical Splash Protection

ASTM F903 (as specified in NFPA 1990/1992) Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids



Multi Hazard GORE-TEX PYRAD® laminate passed ASTM F903 Method C liquid penetration test for common chemicals found in P&P mills

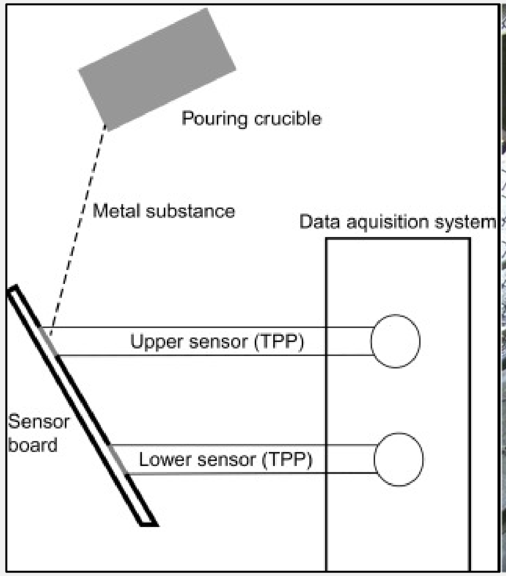
Chemical Penetration Resistance ASTM F903, Procedure C	
Chemical Name	**Chemical Penetration Result**
Sulfuric Acid (93%)	Pass, >60 minutes
Phosphoric Acid (55%)	Pass, >60 minutes
Nitric Acid (69%)	Pass, >60 minutes
Sodium Hydroxide (50%)	Pass, >60 minutes
Ammonium Hydroxide (32%)	Pass, >60 minutes
Benzene	Pass, >60 minutes
Methanol	Pass, >60 minutes
Methyl Ethyl Ketone	Pass, >60 minutes
White Liquor (CAS #68131-30-6)	Pass, >60 minutes
Green Liquor (CAS #68131-30-6)	Pass, >60 minutes
Black Liquor (CAS #66071-92-9)	Pass, >60 minutes
Toluene	Pass, >60 minutes
Hydrogen Peroxide (50%)	Pass, >60 minutes
Sodium Hypochlorite (20%)	Pass, >60 minutes

(Partial list offered here but Gore has tested hundreds of chemicals to support industry)

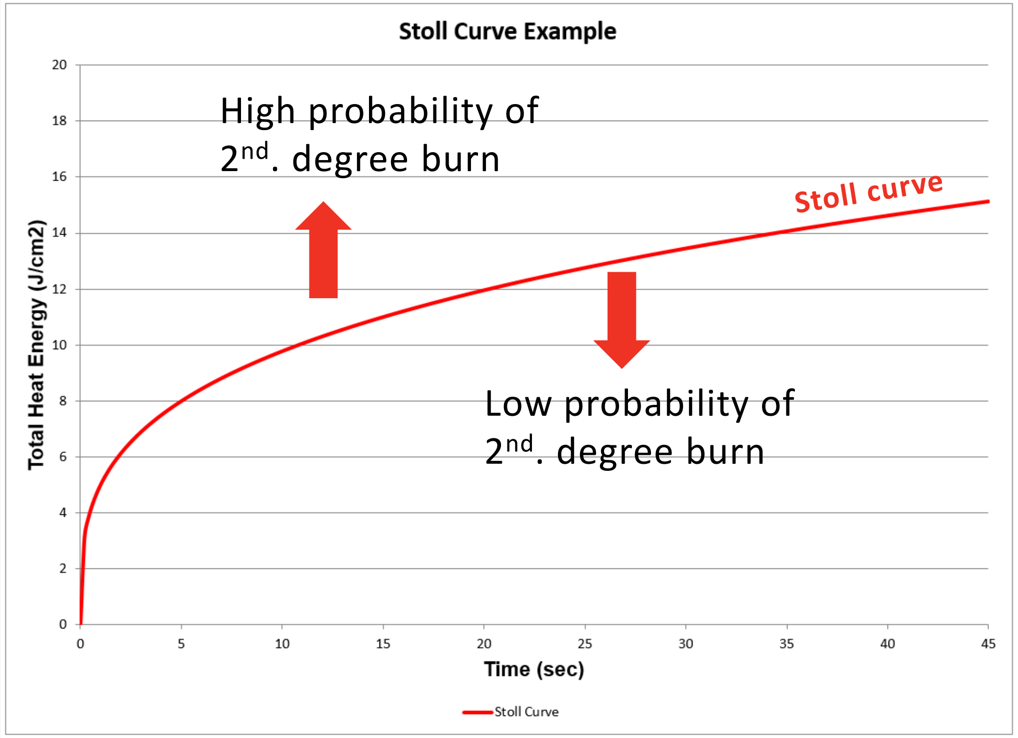
FITNESS FOR USE TESTING: HOT LIQUID CHEMICAL SPLASH

Test Method for Hot Liquid Chemical Splash Protection

ASTM F955, is the Standard Test Method for Evaluating Heat Transfer through Materials for Protective Clothing Upon Contact with Molten or Hot Substances.



Courtesy of UAB

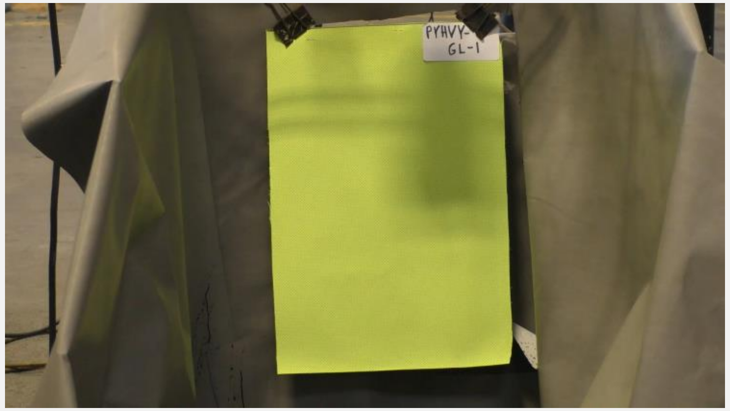


FITNESS FOR USE TESTING: HOT LIQUID CHEMICAL SPLASH

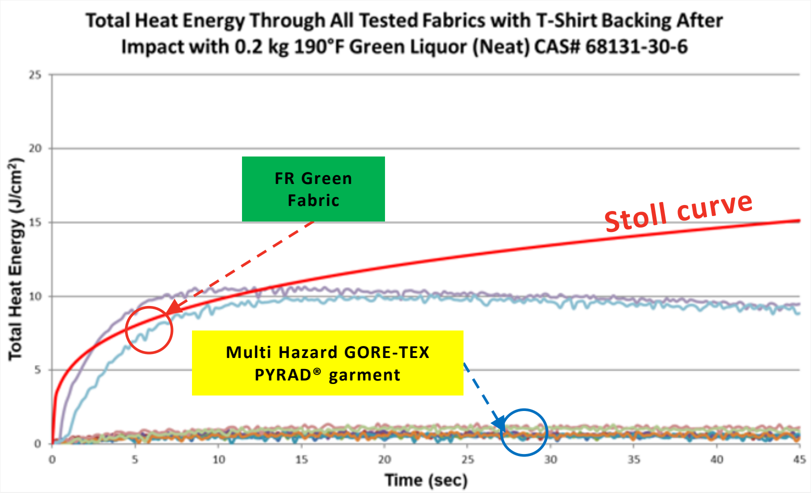
GOING FURTHER, TOGETHER.

FR Green Fabric

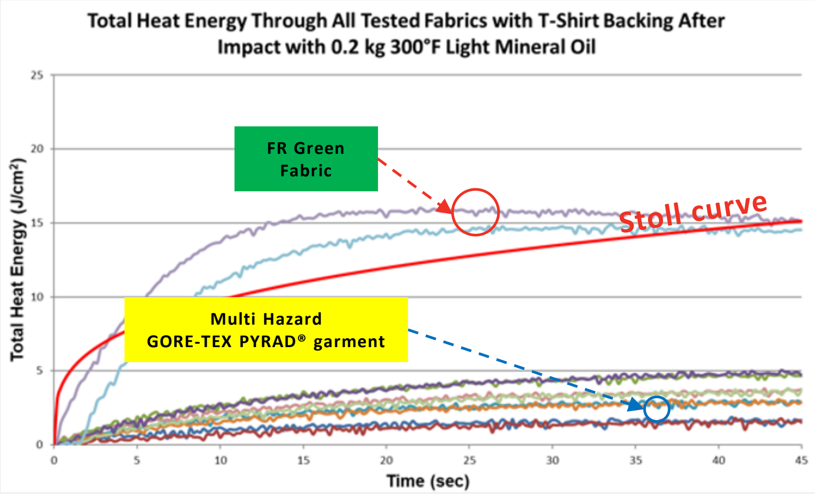
Multi Hazard GORE-TEX PYRAD® garments



Green liquor at 190°F



Mineral Oil at 300°F




GORE-TEX
BRAND
COMFORT STUDIES

R_{ET} - BREATHABILITY MEASURED FOR TRUE COMFORT

GORE-TEX BRAND

GOING FURTHER, TOGETHER.

Breathability test methods vs Resistance to Evaporation of Textile (R_{ET})

Heat stress results from the interaction of:

- Climate conditions
- Body heat production
- Clothing or equipment

R_{ET} testing is precise and at controlled conditions:

- Accurate and reproducible results
- Simulates the actual interaction between body and textile garments
- R_{ET} value measured with the Skin Model correlates directly with the wearer's skin wetness (comfort) or the garments

Lower Resistance (R_{ET}) = Higher Breathability

PPE TO MITIGATE HEAT STRESS

GOING FURTHER, TOGETHER.

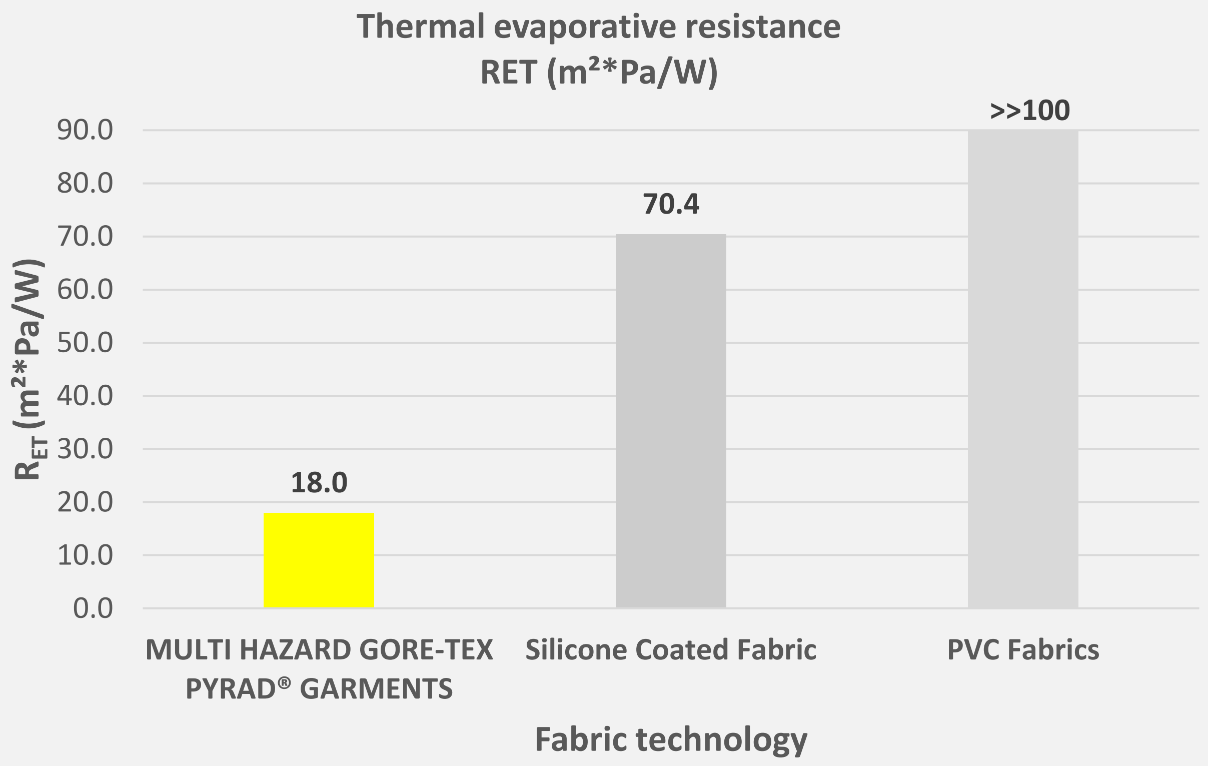
Laminate Breathability – ISO 11079

Evaporative Resistance (Ret)

Hohenstein Breathability Rating Scale

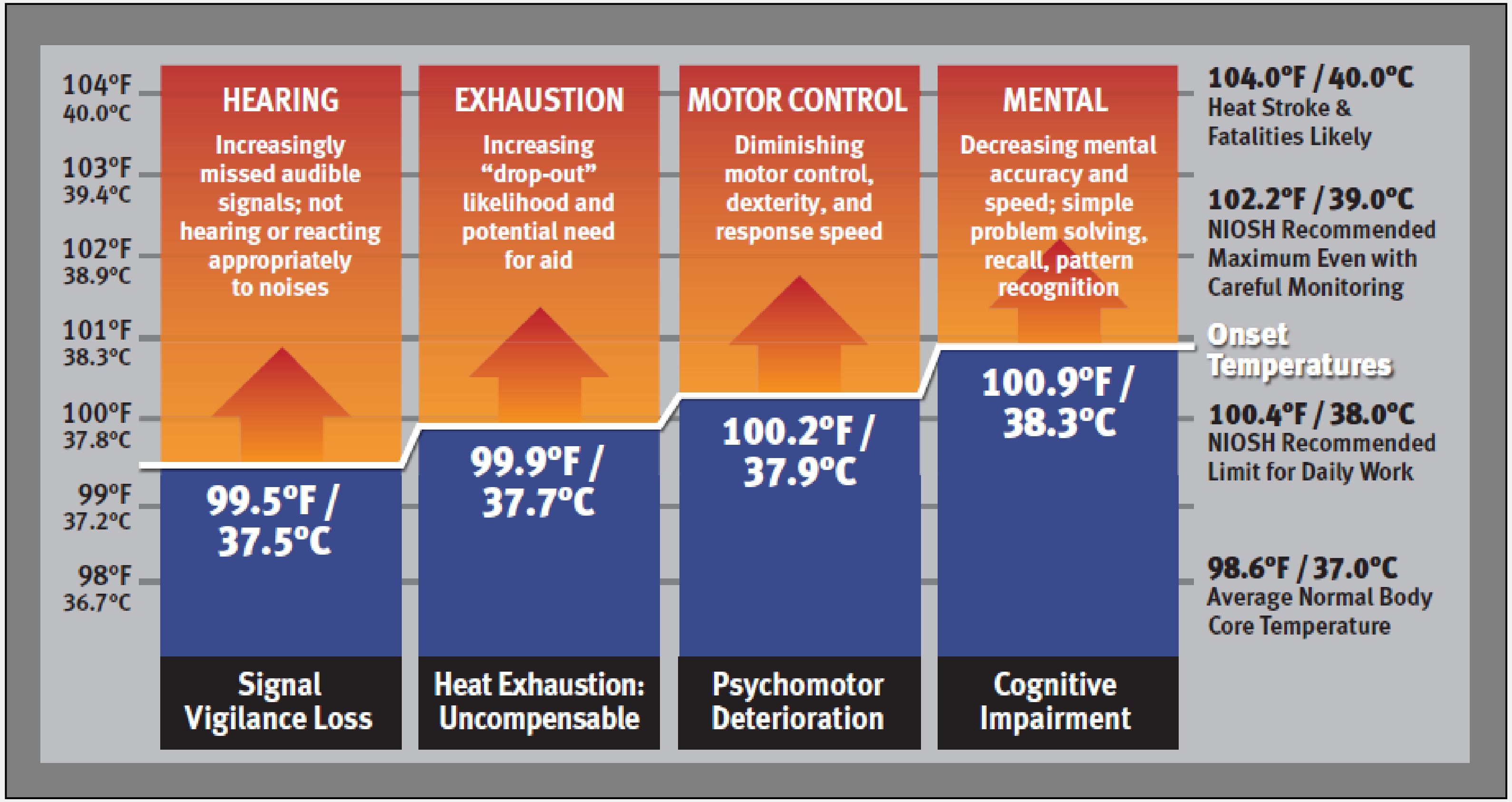
Rating	R_{et} (m^2 Pa/W)
Extremely Breathable	<6
Very Breathable	6-13
Breathable	13-20
Low Breathability	20-30
Not Breathable	>30

K. H. Umbach, "Physiological and Technological Aspects of Clothing of Water-Repellent Textile Constructions Permeable to Water Vapor at the Same Time," Hohenstein Technical Report, Research Project AIF-NO 5296



PERFORMANCE IMPACTS RESULTING FROM OF HEAT STRAIN

GOING FURTHER, TOGETHER.



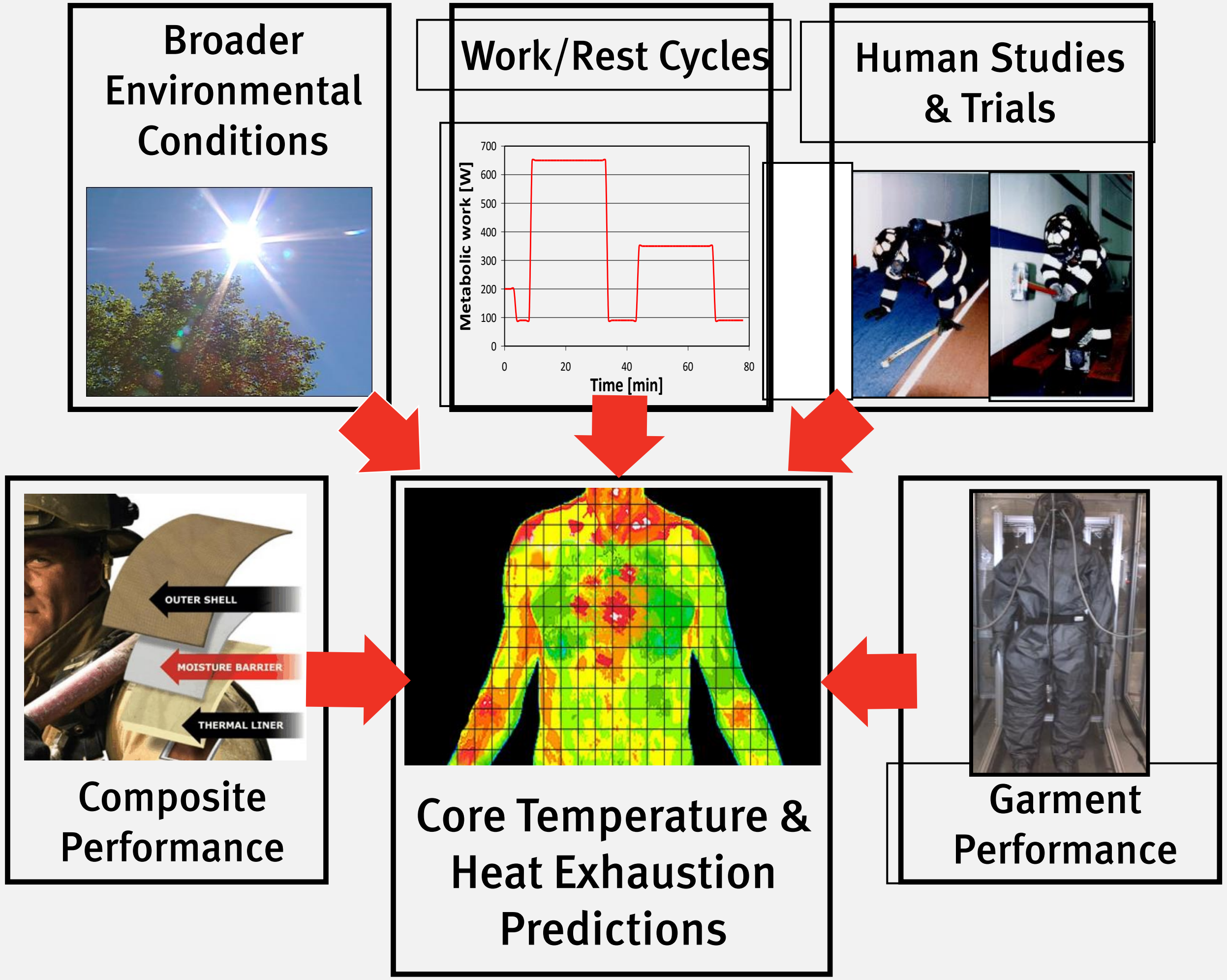
- Small changes in core temperature can make large differences in human comfort and performance.
- Sense of scale: There is only 1°C difference between 'normal' core temperature and the NIOS. recommended core temperature limit for daily work. The difference between this limit and a high likelihood of Heat Stroke/Fatalities is only 2°C.
- Typical meaningful threshold for meaningful core temperature differences in a heat stress scenario is 0.1 – 0.15 °C.

PHYSIOLOGICAL MODELING

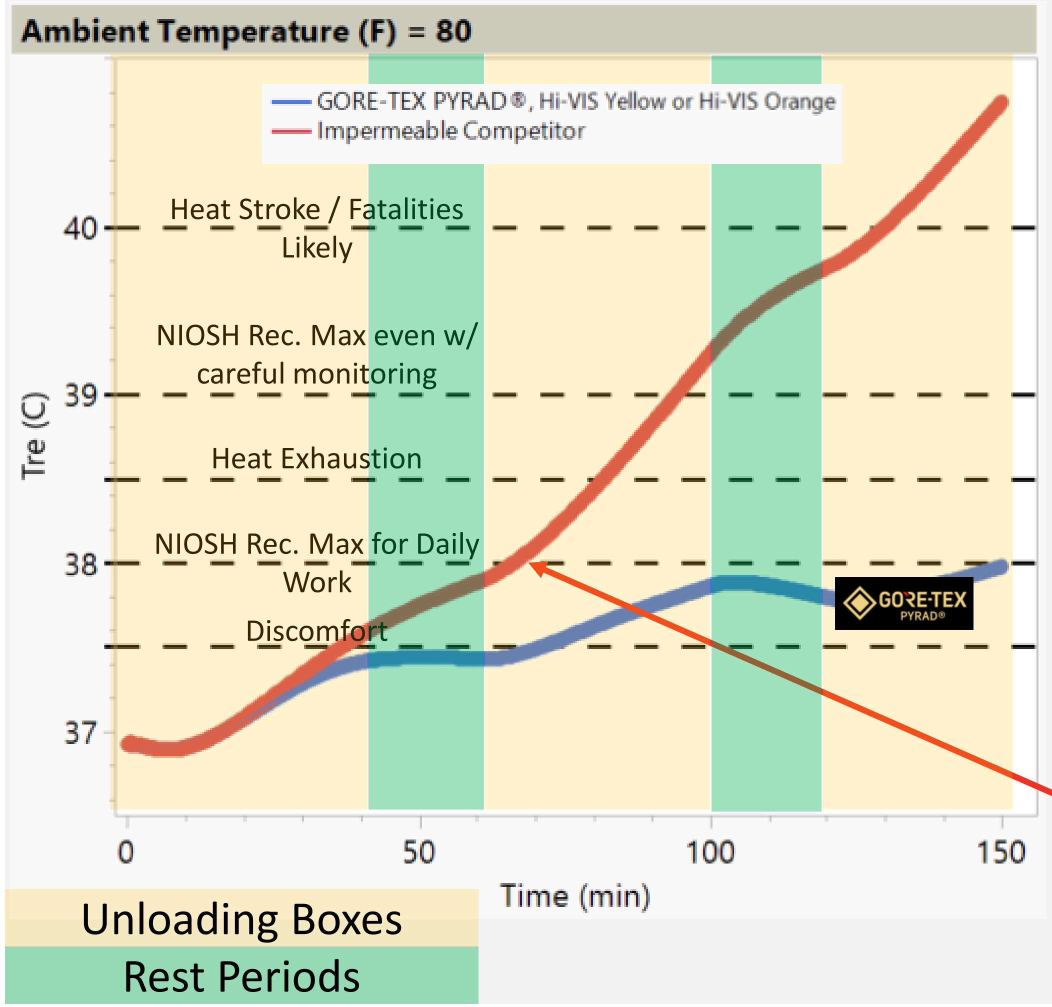
GORE-TEX

GOING FURTHER, TOGETHER.

Through the experienced use of field-proven thermophysiological models, combined with proprietary capabilities including testing over a broad range of environments, Gore is able to make effective predictions of how different PPE technologies help to manage heat stress, and determine some of the impact on the human body.



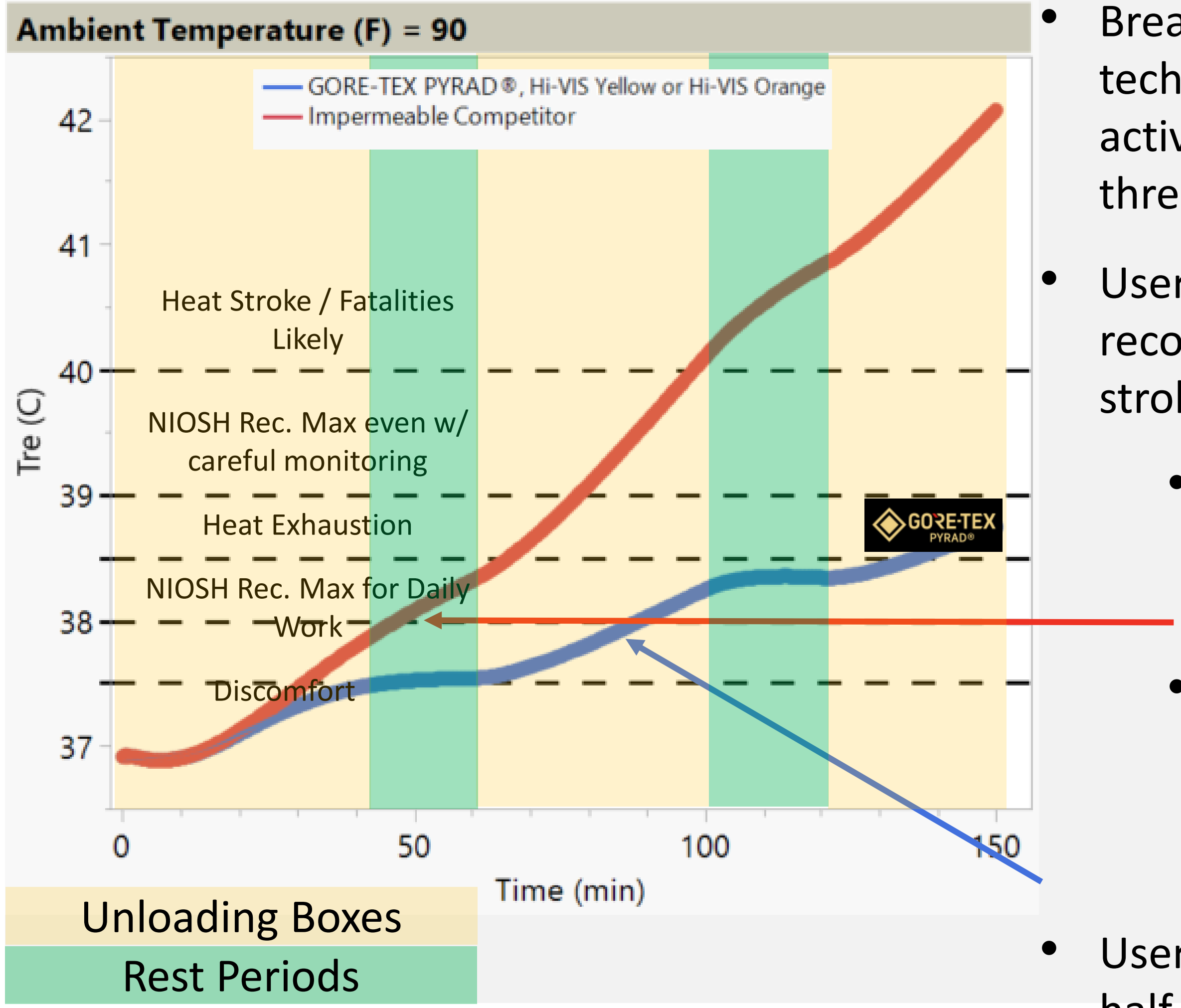
PHYSIOLOGICAL MODELING CASE STUDY – UNLOADING A TRUCK WEARING PPE @ 80°F



- Breathable **Multi Hazard GORE-TEX PYRAD® garment** fabric technology allows the worker to complete the entire bout of activity while remaining under the NIOSH recommended maximum core temp. for daily work
- User in an impermeable suit would greatly exceed the recommended maximum core temperatures and likely suffer heat stroke if following this prescribed work/rest cycle
  - High risk of severe and dangerous rises in core temperature.
  - This worker would be forced to take more/longer breaks and decreased efficiency
- User wearing an impermeable suit could only work at this rate for around one hour before exceeding the NIOSH recommended maximum core temp. for daily work.

PHYSIOLOGICAL MODELING CASE STUDY – UNLOADING A TRUCK WEARING PPE @ 90°F

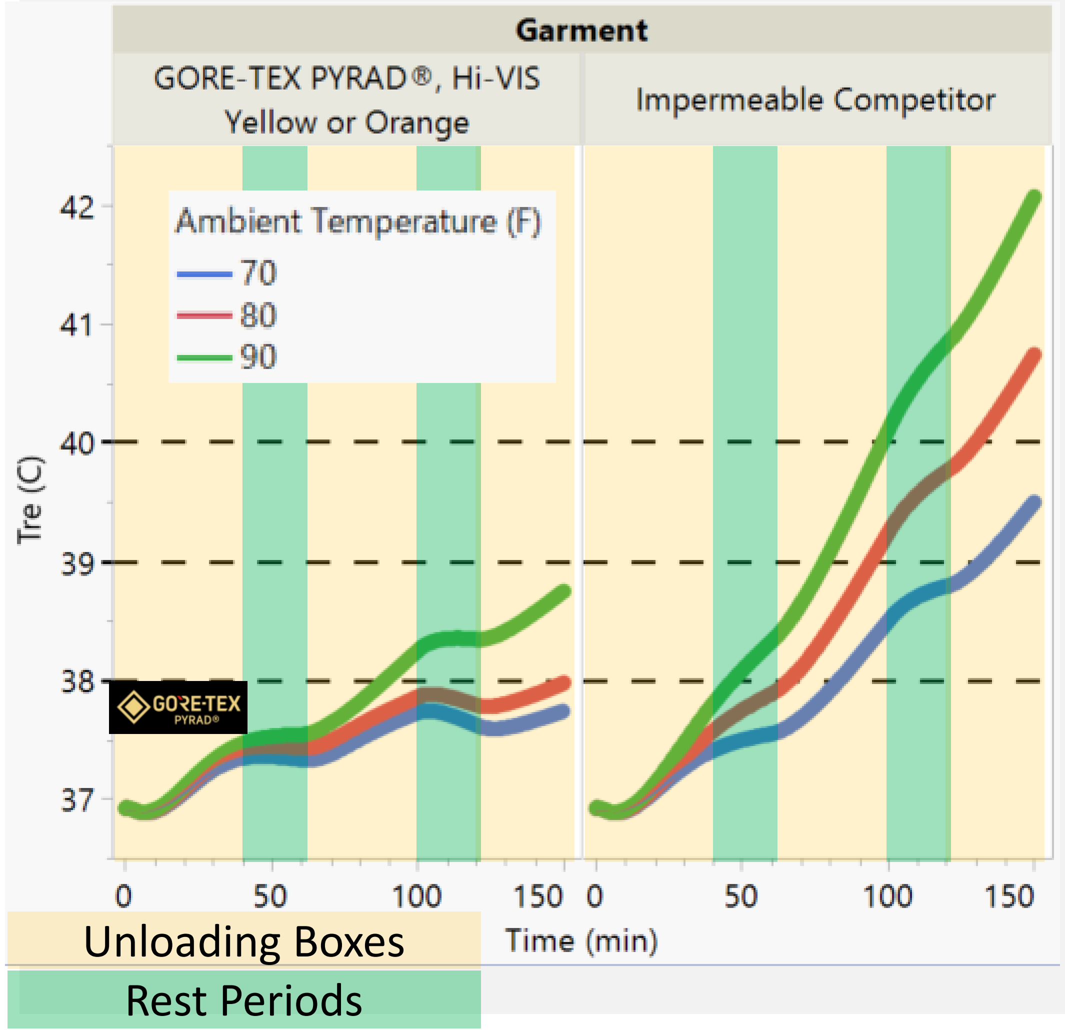
GOING FURTHER, TOGETHER.



- Breathable **Multi Hazard GORE-TEX PYRAD® garment** fabric technology allows the worker to complete the majority of the activity while remaining under the heat exhaustion 40% dropout threshold
- User in an impermeable suit would greatly exceed the recommended maximum core temperatures and likely suffer heat stroke if following this prescribed work/rest cycle
  - High risk of severe and dangerous rises in core temperature when wearing an impermeable suit in this environment – Much lower risk with a breathable suit
  - Worker in an impermeable suit would be forced to take more/longer breaks and/or doff the garments during the breaks to avoid this dangerous rise in core temperature – severely decreased efficiency
- User wearing Gore technology could work for around an hour and a half before exceeding the NIOSH recommended max – Worker in an impermeable suit could only work half that time

PHYSIOLOGICAL MODELING CASE STUDY – THE BIG PICTURE

GORE-TEX BRAND
GOING FURTHER, TOGETHER.



- Small changes in core temperature can make large impacts to end user safety and performance!
- The potential for heat stress increases as the ambient temperature rises – heat stress mitigation becomes even more important
  - Gore technology mitigates the increased thermal burden by providing optimized breathability to allow for efficient sweat evaporation
  - This sweat evaporation allows the end user to balance his heat production with heat loss – minimizing the dangerous rise in core temperature
- **Multi Hazard GORE-TEX PYRAD® garment** allows the end user to perform their work **more safely**, with **less breaks** and **higher efficiency** by mitigating heat stress when it matters most

SUMMARY

MULTI HAZARD GORE-TEX PYRAD® GARMENTS

GOING FURTHER, TOGETHER.

Single Garment Providing Protection from Multiple Mill Hazards

Jacket

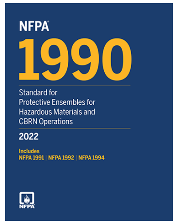
50" Coat

Hood

Bib Overall

Coverall

- Liquid Chemical Splash protection
- Inherently Flame Resistant Flash Fire protection
- Arc Flash Protection
- Breathable
- Light weight
- Long lasting performance after washing



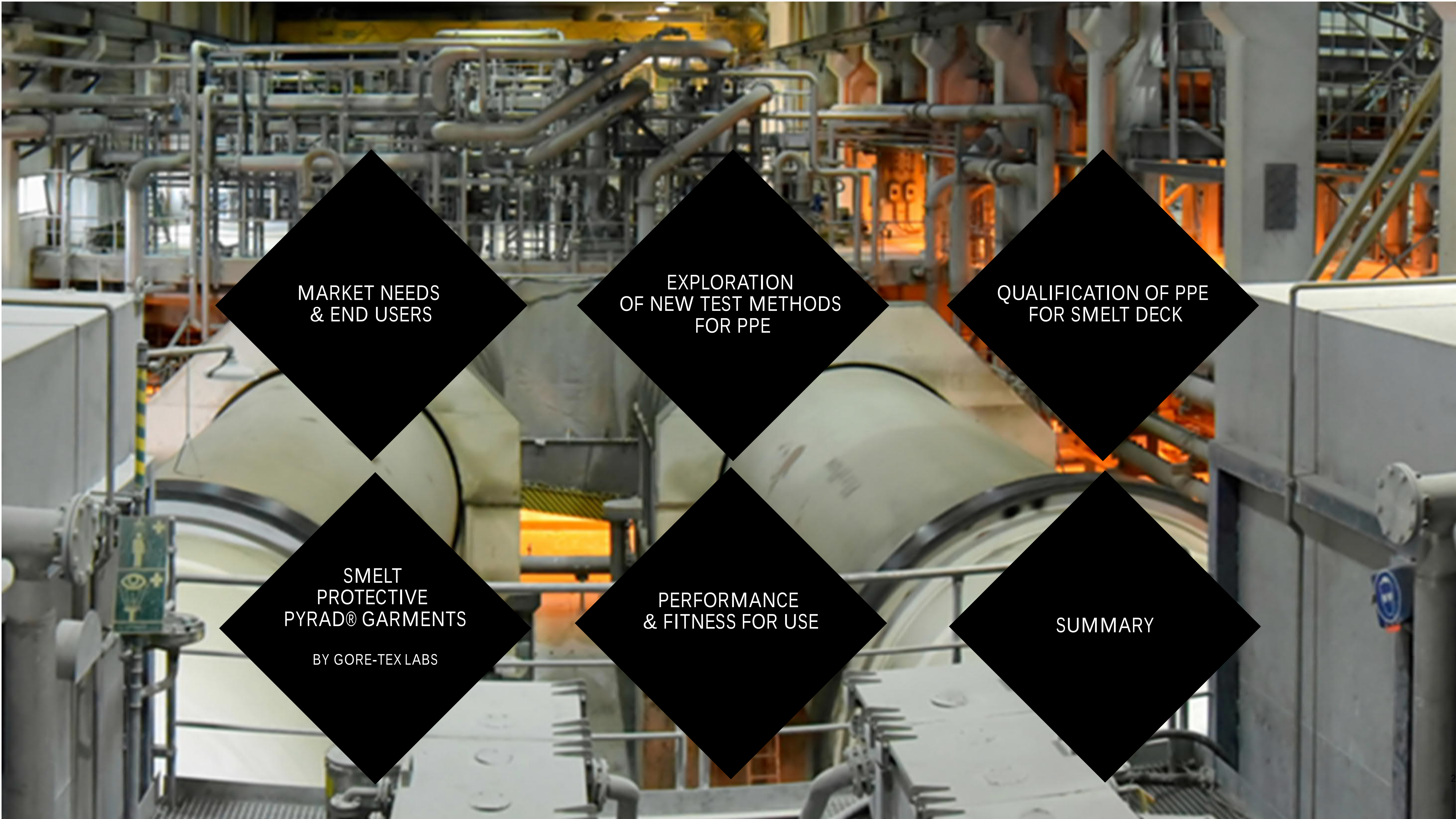

GORE-TEX
BRAND
THANK YOU

GORE-TEX
BRAND

RECOVERY BOILER PPE SMELT DECK PROTECTION GORE & VALMET

JIM ELLIS & PAUL DACEY
W. L GORE & ASSOCIATES
TECHNICAL ORIENTED FABRICS

Feb 2nd, 2022


MARKET NEEDS
& END USERS
EXPLORATION
OF NEW TEST METHODS
FOR PPE
QUALIFICATION OF PPE
FOR SMELT DECK
SMELT
PROTECTIVE
PYRAD® GARMENTS
BY GORE-TEX LABS
PERFORMANCE
& FITNESS FOR USE
SUMMARY

GORE-TEX
BRAND

MARKET NEEDS & END USERS

Courtesy of Valmet

HAZARDS FROM RECOVERY BOILER OPERATIONS

The recovery boiler is a vital part of the pulp mill but also a source of potential safety hazards for its operators.

- Purposes of a recovery boiler:
  - One of the purposes of the recovery boiler is to recover the pulping chemicals from the black liquor which is done in the form of smelt from the bottom of the furnace.
  - Smelt is a mixture of Sodium carbonate and Sodium Sulfate operating at 1200-1700 °F.
- The spout deck on a recovery boiler is considered the most dangerous area for operators and one of the leading causes of recordable injuries.
  - A potential hazard of this process is if the smelt interacts or has contact with water, an explosion can potentially occur which could injure operators.
- Operators are also at risk of injury, working around the liquor guns or taking liquor samples.


Courtesy of Valmet

CHALLENGING CONDITIONS REQUIRE OUTSTANDING SOLUTIONS

Valmet FORWARD

GORE-TEX BRAND

GOING FURTHER, TOGETHER.

Reducing the risk of serious burns or injuries is exceptionally important for mills with recovery boiler operations.

- Operators are typically required to wear cumbersome PPE to resist splash of molten smelt while performing demanding work on the deck.
- Available PPE tend to be:
  - Relatively heavy and thick (multi-layers), causing muscular fatigue and hindering mobility.
  - Non-breathable, resulting in heat build-up, thermal discomfort and longer breaks to recover from potential heat stress.
  - Limited thermal protective, potentially resulting in burn injuries

GORE-TEX
BRAND

QUALIFICATION OF PPE FOR SMELT DECK

Courtesy of Valmet

MARKET EXPLORATION JOURNEY

GOING FURTHER, TOGETHER.

Pulp and paper market exploration

In-depth interviews with end-users

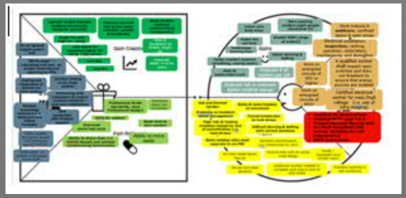
Boiler chiefs, corporate EH&S, Safety Consultants and contractors at paper mills

Source of interviews:

Valmet field service team, associations, BLRBAC & AFPA

Key Objectives:

Find the safety problem the mills are the most compelled to solve and develop a solution for it



EXPLORATION OF NEW TEST METHODS FOR PPE

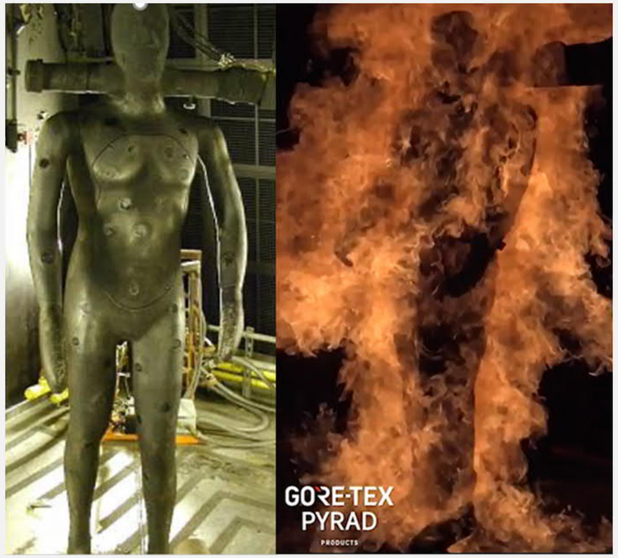
GOING FURTHER, TOGETHER.

Gore commits to deliver products that meet our customer´s expectation and are fit for their intended use:

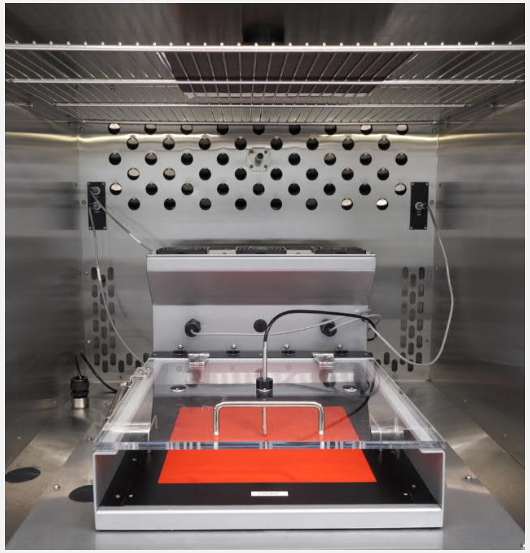
- Delivering products that meet requirement according to Standards.
- Understanding end-user needs, final product end-use and material science.

Vertical flame test

PYROMAN™



Sweating hot plate



Thermal comfort

EXPLORATION OF NEW TEST METHODS FOR PPE

Courtesy of Valmet

QUALIFICATION OF PPE FOR SMELT DECK

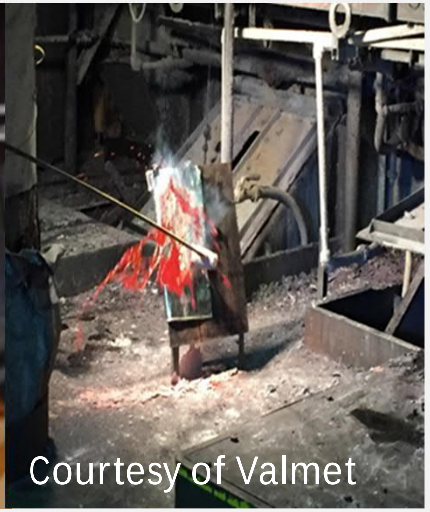
GOING FURTHER, TOGETHER.

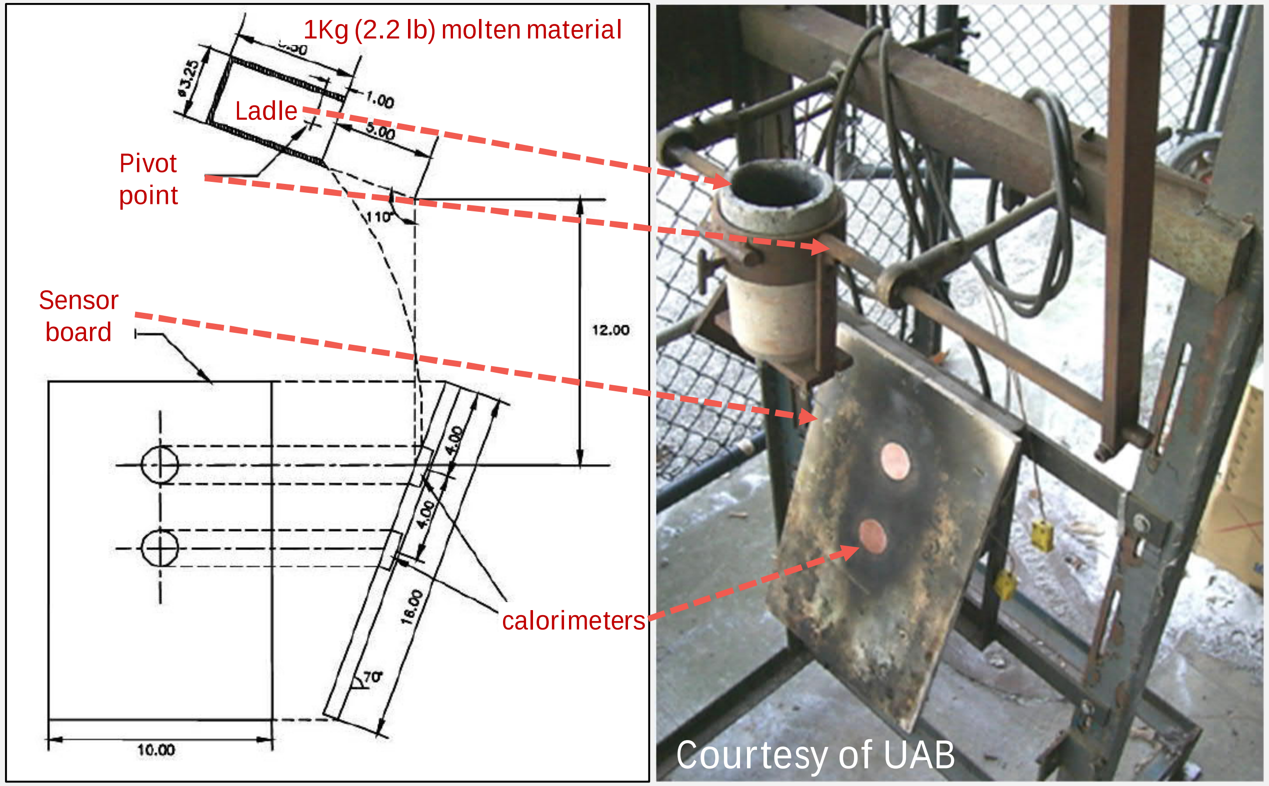
ASTM F955: Evaluating heat transfer through materials for protective clothing upon contact with molten substances.

Outcome: Predicted 2nd degree burn injury determination (Stoll Curve Comparison)

Recovery boiler operation

Mill splash testing



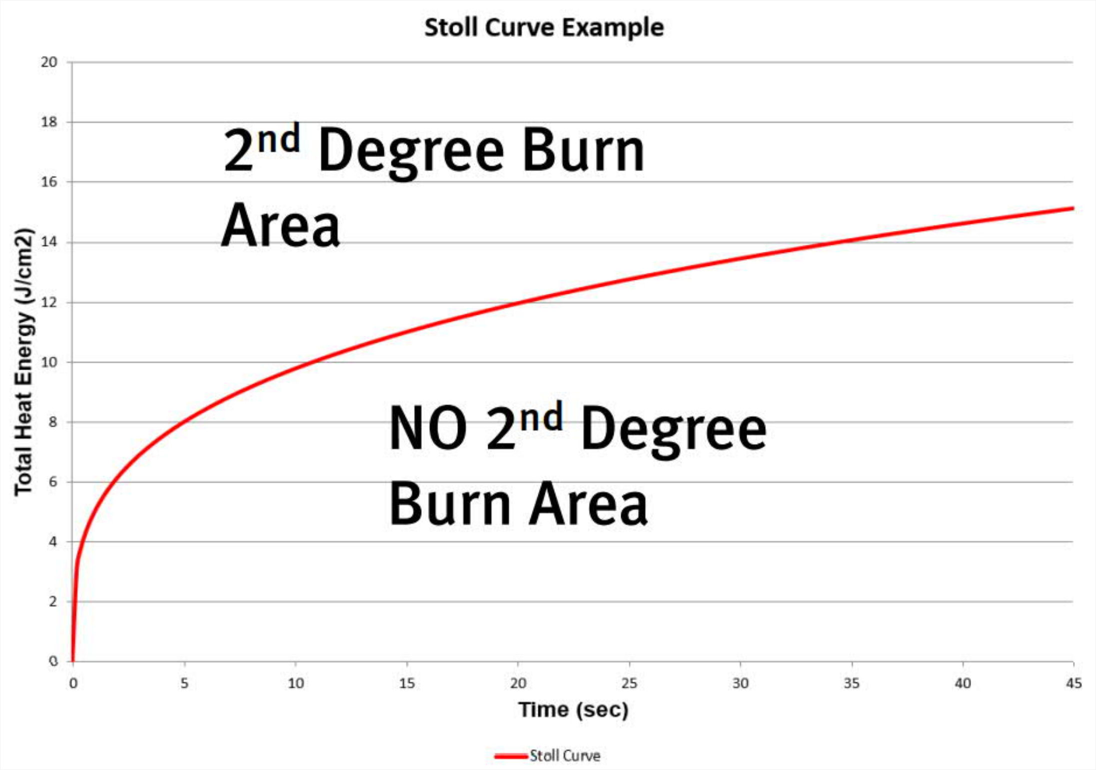


THE STOLL CURVE AND PPE FOR SMELT PROTECTION

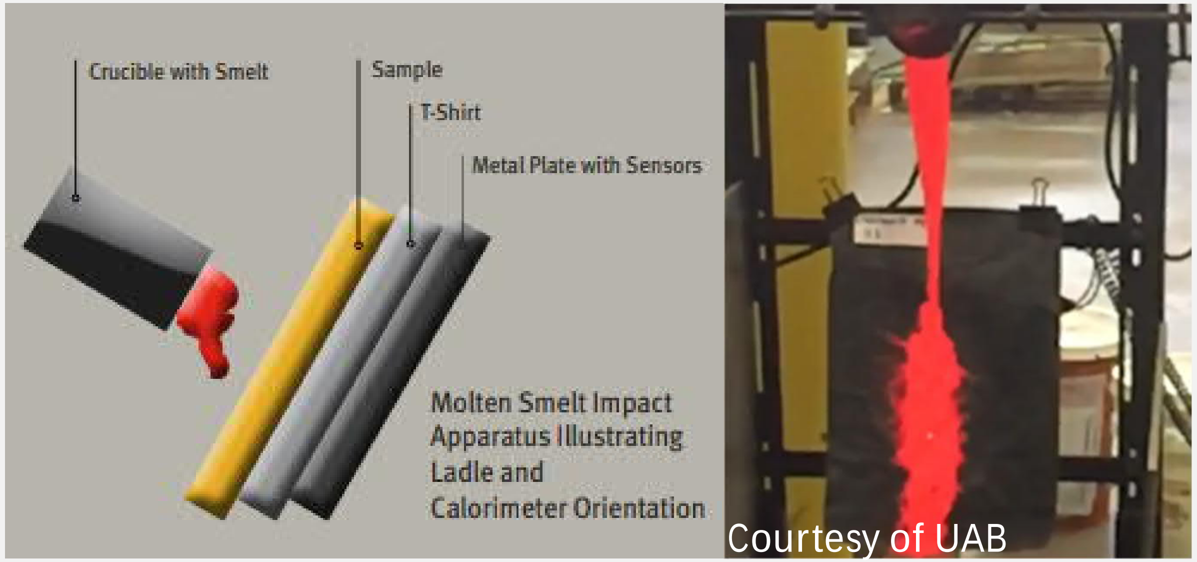
GORE-TEX BRAND

GOING FURTHER, TOGETHER.

The Stoll Curve: The Stoll Curve determines the rating of the transfer of heat energy based on the time of transfer and the level of heat energy produced



Test set up:
Confirmed by interviewing chiefs "500g (1.1lb) smelt exposure would be a "worst-case scenario" and protection from that amount would demonstrate very good material performance"



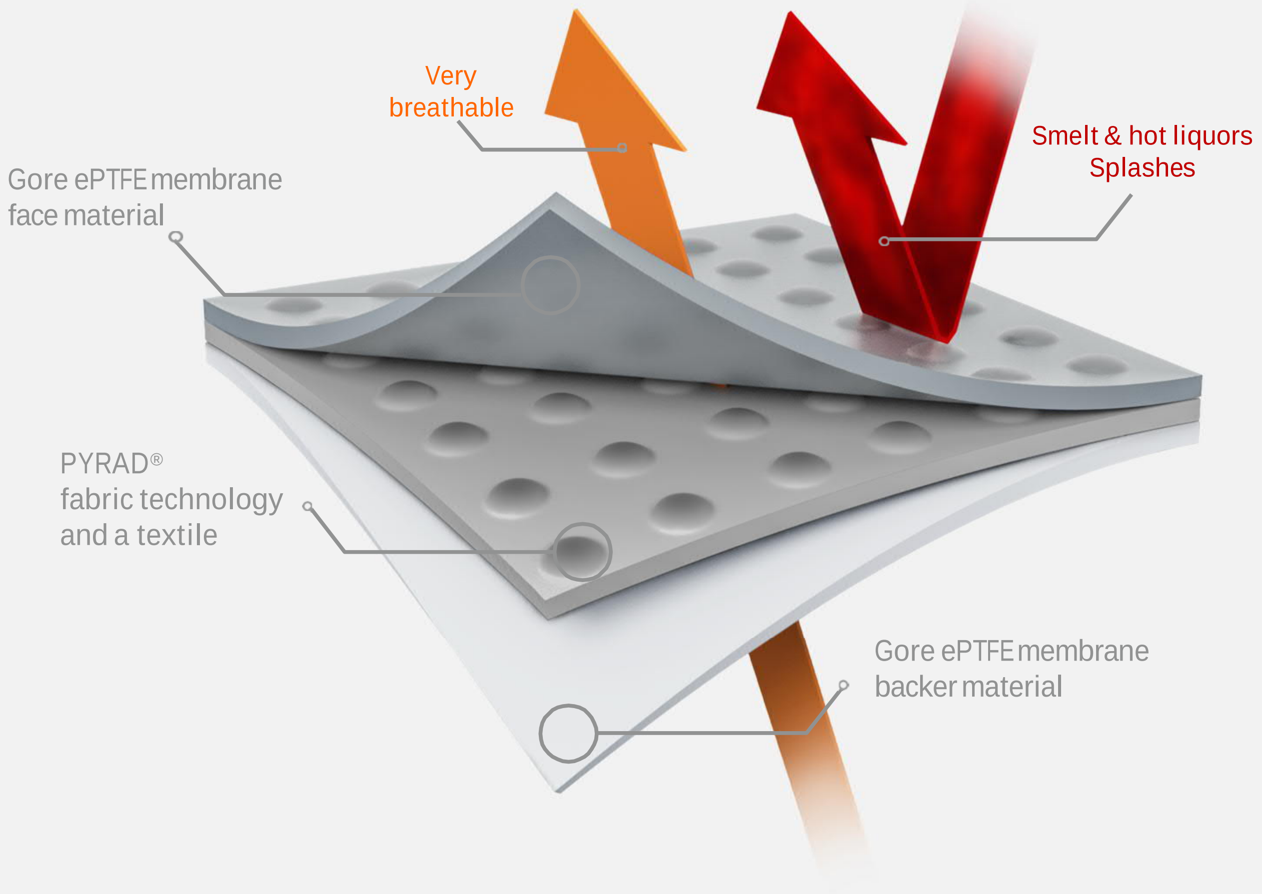

GORE-TEX
BRAND
SMELT PROTECTIVE PYRAD® GARMENTS
BY GORE-TEX LABS

THE SCIENCE BEHIND OUR TECHNOLOGY

GOING FURTHER, TOGETHER.

Smelt Protective PYRAD® Garments by GORE-TEX LABS

- 3 functional layers engineered into 1 ply
  - Inherently FR
  - Wash durable

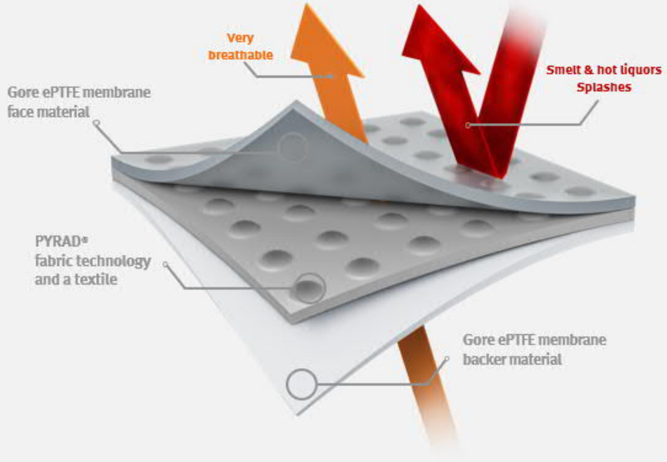


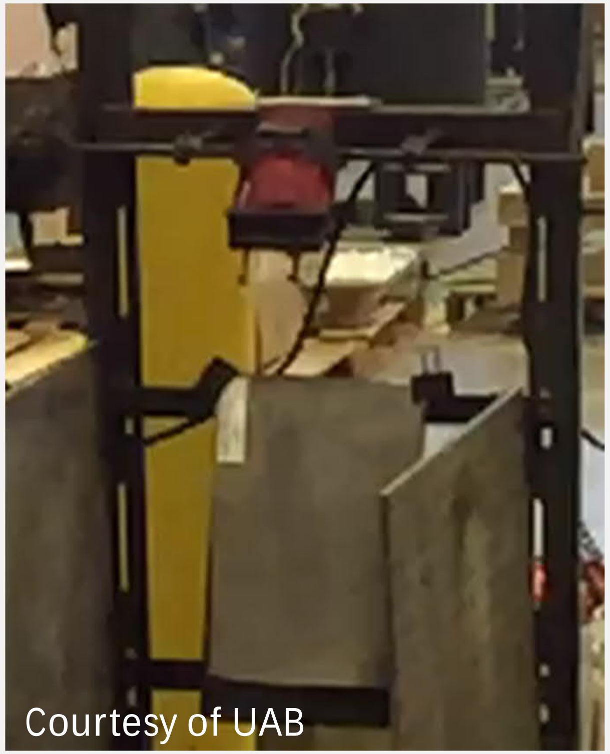
THE SCIENCE BEHIND OUR TECHNOLOGY

GOING FURTHER, TOGETHER.

Current Pulp and Paper PPE may not be smelt protective

Smelt Protective PYRAD® Garments by GORE-TEX LABS





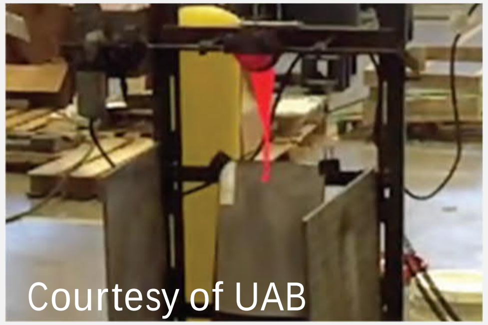
THE SCIENCE BEHIND OUR TECHNOLOGY

GOING FURTHER, TOGETHER.

During an incidental smelt or liquor splash exposure :

1

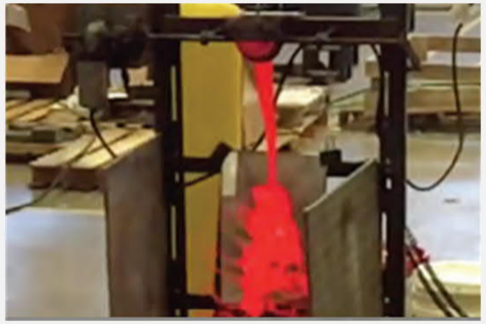
Single-ply
Smelt Protective PYRAD® Garment by GORE-TEX Labs



Before smelt splash.

2

Face material, Gore ePTFE membrane



Strong, thermally stable, and breathable layer that enables quick shedding to reduce the transfer of heat energy.

3

The PYRAD® Fabric Technology

Blocks heat flow to the skin (absorbs the thermal energy) and stops flame propagation by forming an insulative carbonaceous char with the textile (without melting or dripping).

4

Backer material, Gore ePTFE membrane

Ensures that physical integrity is maintained after heat and flame exposure. No break or hole formation.

5

Base layer
Cotton shirt

Best-in-class mechanical integrity with no hole formation to the innermost layer.

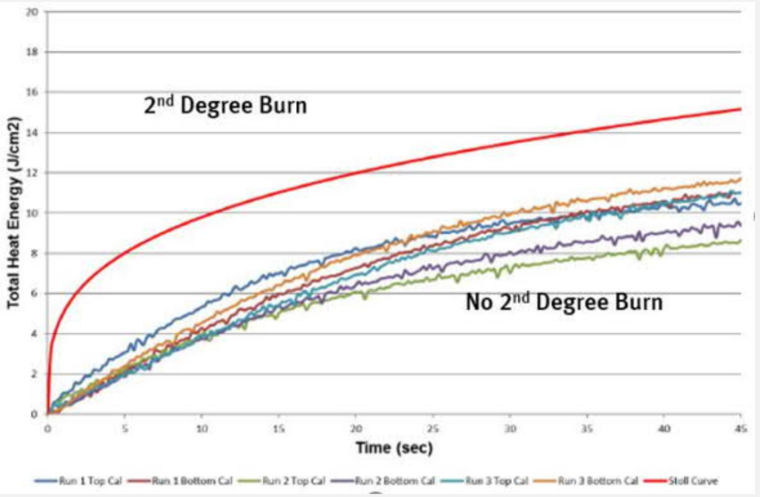

GORE-TEX
BRAND
PERFORMANCE
&
FITNESS FOR USE

ASTM F955 – SMELT SPLASH ON FABRIC TECHNOLOGIES

GOING FURTHER, TOGETHER.

Total energy through fabric technologies with T-shirt backing after impact with 0,5 Kg molten smelt

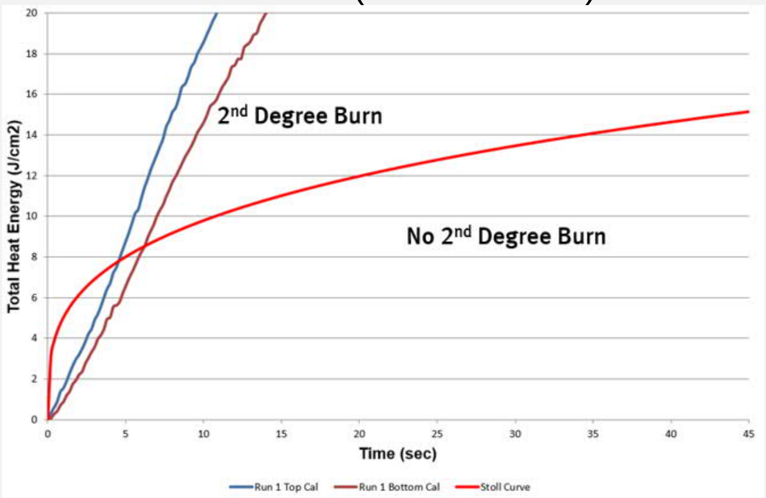
Smelt Protective PYRAD® Fabric



Outside

Inside

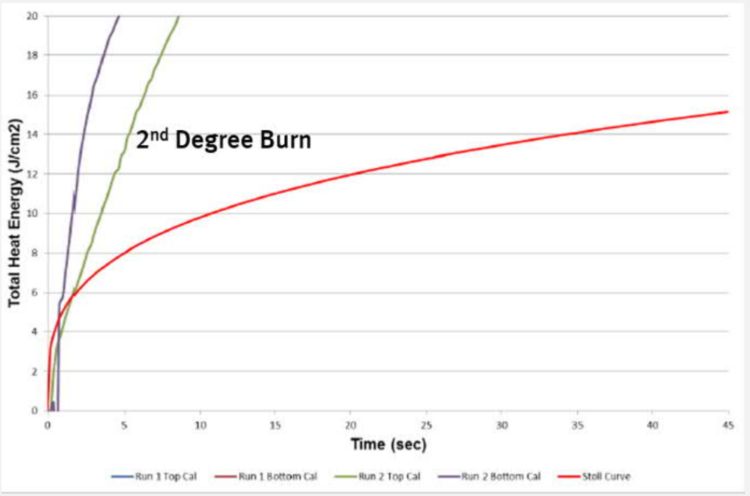
Material A (Coated fabric)



Outside

Inside

Material B (Aramid fabric)



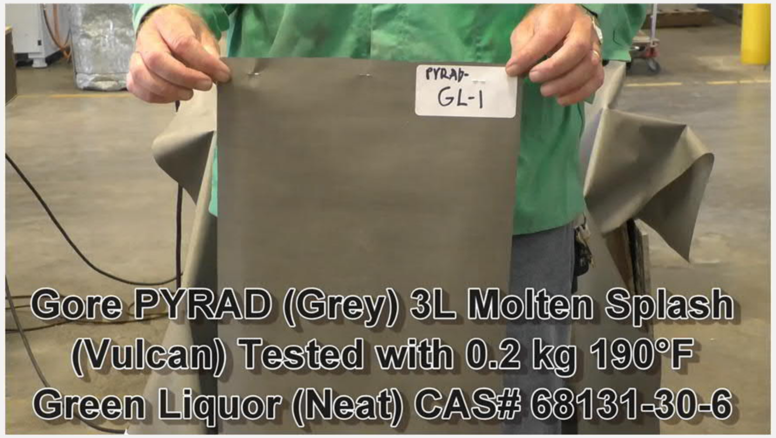
Outside

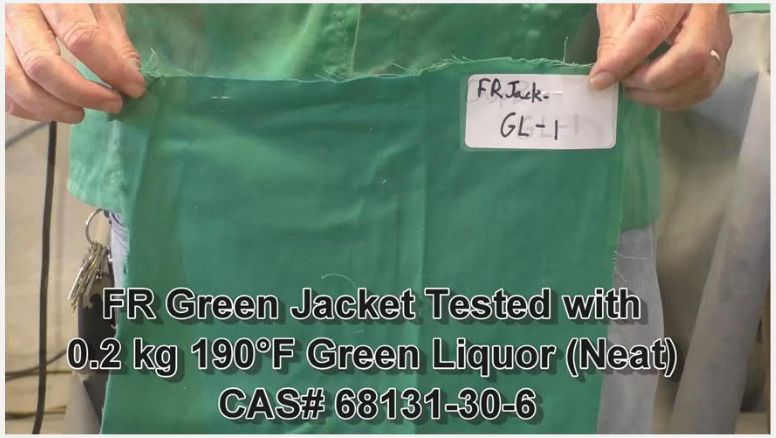
Inside

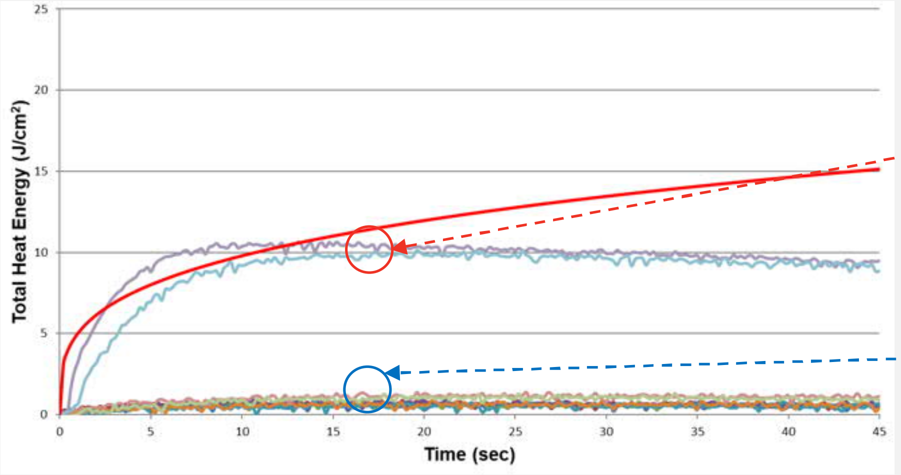
ASTM F955 - AFTER IMPACT WITH 0,2 KG PAPER MILL LIQUORS

GOING FURTHER, TOGETHER.

Green liquor at 190°F (88°C)



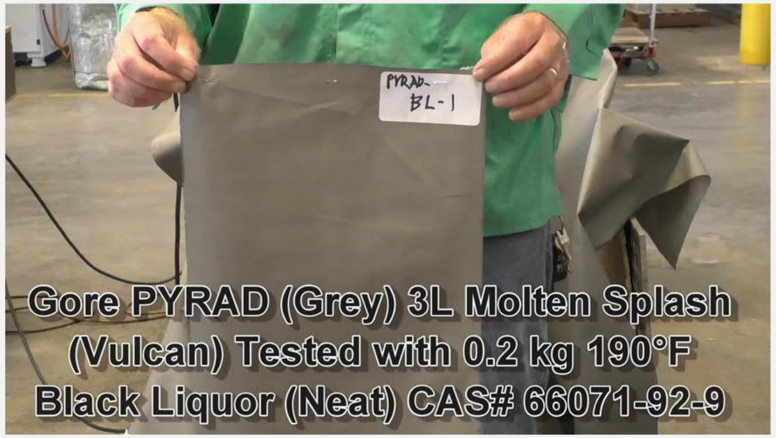




FR Green Fabric

Smelt Protective PYRAD® fabric technology "quick shedding mechanism"

Black liquor at 190°F (88°C)



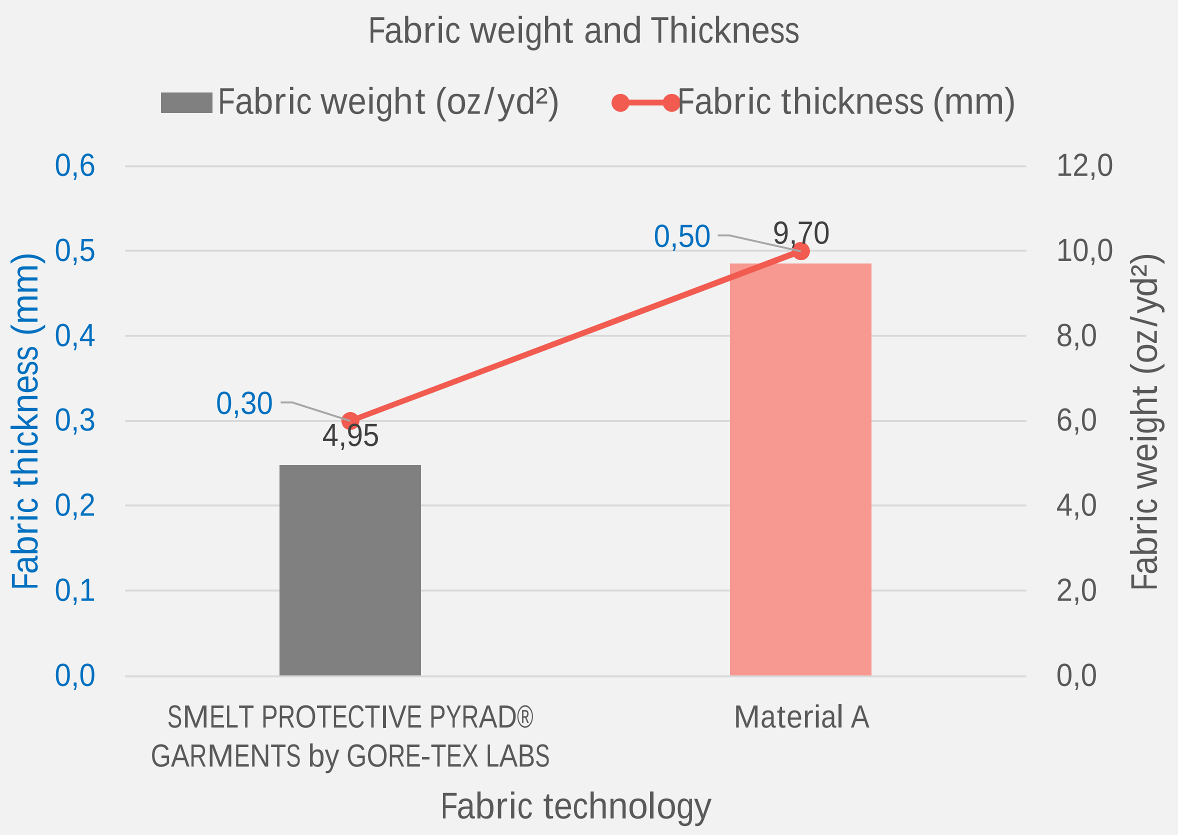
"Quick shedding and additional protective mechanisms"

LIGHTEST WEIGHT AND THIN SMELT PROTECTION

GOING FURTHER, TOGETHER.

The benefits of Smelt Protective PYRAD® fabric technology:

- Up to 55% lighter and 60% thinner (less bulky) when compared to PPE used currently for smelt protection in the P&P mills.
- It enables freedom of movement and light weight garments reducing fatigue and increasing productivity.



R_{ET} - BREATHABILITY MEASURED FOR TRUE COMFORT

GOING FURTHER, TOGETHER.

Heat stress results from the interaction of:

- Climate conditions
- Body heat production
- Clothing or equipment

Resistance to Evaporation of Textile (R_{ET}):

- Material property that describes how much a material hinders the evaporation of sweat away from your body.
- R_{ET} value measured with the Skin Model correlates directly with the wearer's skin wetness (comfort) or the garments (ISO 11092 / ASTM F1868).

Hohenstein Comfort Rating System:

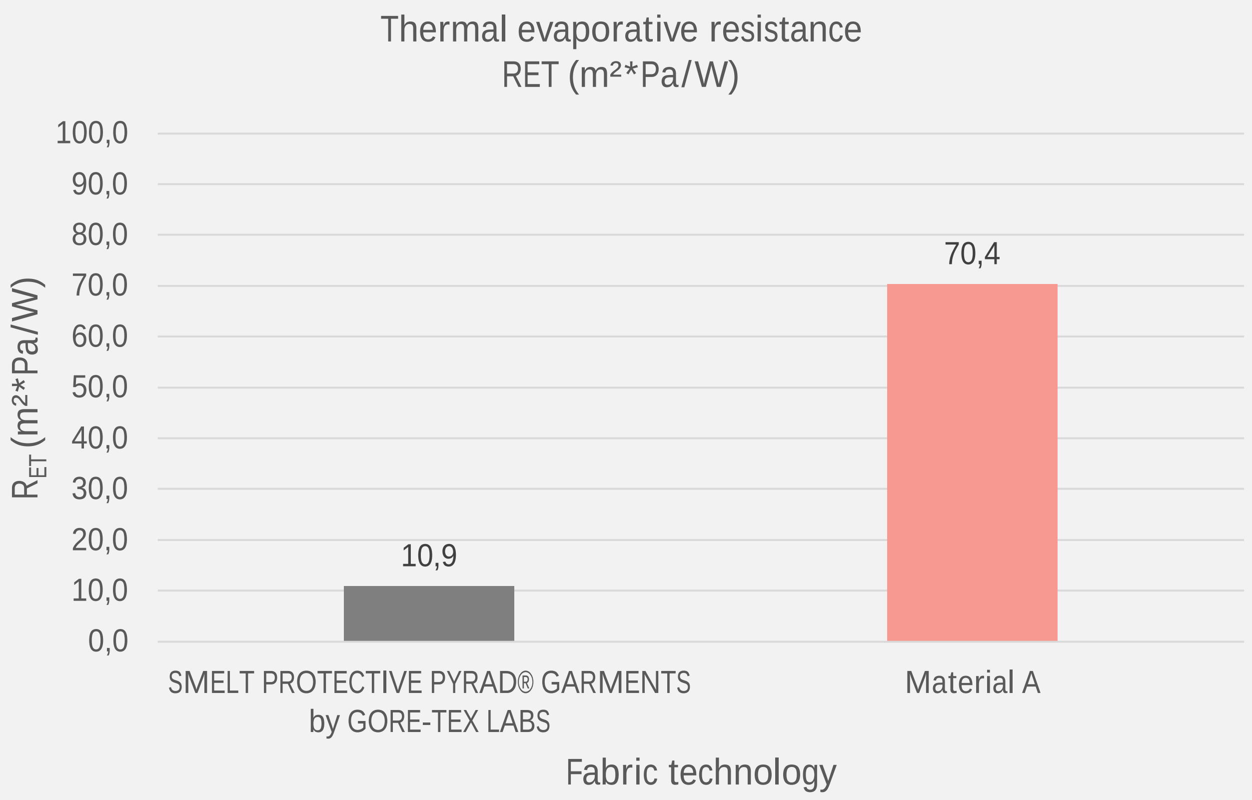
Ret RANGE	RATING
0 to 6 m²Pa/W	Very good or extremely breathable. Comfortable at higher activity rate.
6 to 13 m²Pa/W	Good or very breathable. Comfortable at moderate activity rate.
13 to 20 m²Pa/W	Satisfactory or breathable. Uncomfortable at high activity rate.
20 to 30 m²Pa/W	Unsatisfactory or slightly breathable. Moderate comfort at low activity rate.
30+ m²Pa/W	Unsatisfactory or non-breathable. Uncomfortable at short tolerance time.

THE MOST BREATHABLE SMELT PROTECTIVE PPE FABRIC

GOING FURTHER, TOGETHER.

Highly breathable fabrics/garments keep the wearers dry from inside and comfortable while working in highly physical activities:

- Lower body core temperatures during periods of high intensity work.
- Less accumulation of sweat on the skin.
- A higher R_{ET} value means higher hindrance, leading to increased thermal burden and higher skin wettedness



THERMAL PROTECTION AGAINST INCIDENTAL FLASH FIRE

GOING FURTHER, TOGETHER.

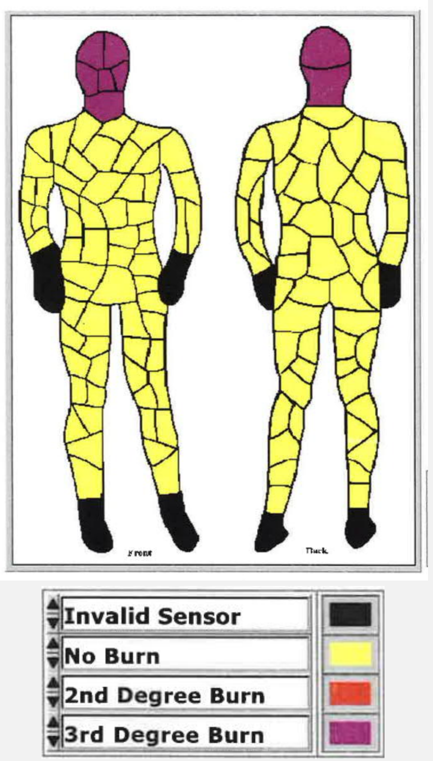
Outstanding FR properties of Smelt Protective PYRAD® fabric technology:

- ASTM F1930 (PYROMAN TM) with less than 40% predicted 2nd degree body burn at 3s exposure when tested over FR Coverall
- ASTM D6413 (Vertical flame test) with and after-flame < 2 sec and Char length < 6 in .

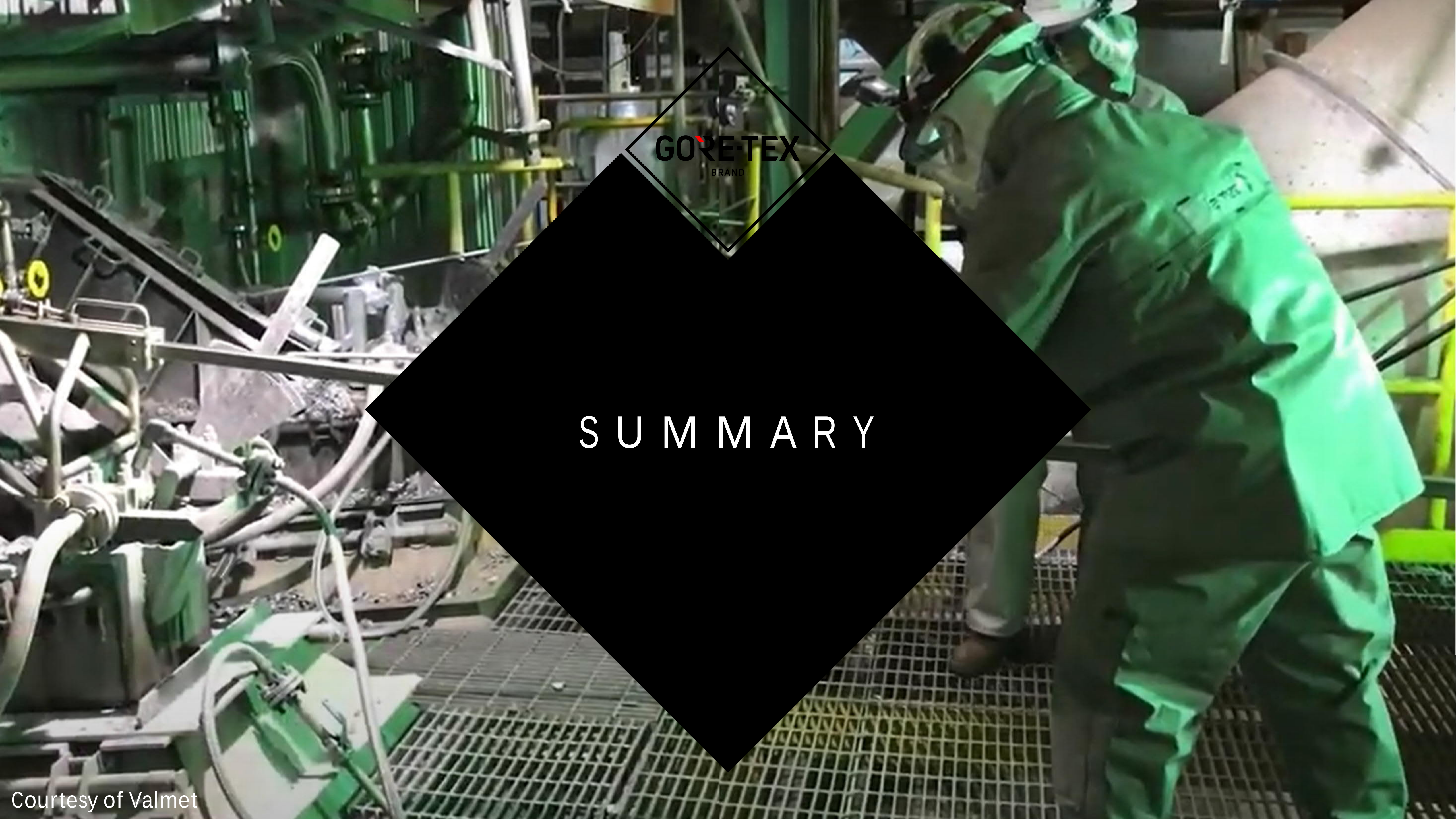
Garment ID: #12

Layer 1: Cotton T-Shirt And Cotton Briefs
Layer 2: Carhartt Cotto, 44R Coverall
Layer 3: Gore FR Boiler Jacket And Pant

Exposure Time (S): 3 sec
Exposure Heat Flux: 2cal/^2sec
File Name: 170419P



SUMMARY



Courtesy of Valmet

SUMMARY

GOING FURTHER, TOGETHER.

Smelt protective PYRAD® garment by GORE-TEX LABS:

- Consistent smelt protective garment that relies upon proprietary novel inherent FR technology (PYRAD® by GORE-TEX labs).
- PYRAD® technology that enables light weight and low bulk garments.
- Highly breathable smelt protective garments to mitigate heat stress.
- Garments tested per ASTM F955 for smelt and liquors.
- Garments tested per ASTM F1930 (PYROMAN™) with low Predicted 2nd degree body burn.
- California Prop 65
- Made in USA - USMCA compliant.

THE NEW SMELT PROTECTIVE PYRAD® GARMENTS BY GORE-TEX LABS

GOING FURTHER, TOGETHER.

- Product forms:

Jacket with hood | Pant | Trench with hood

Key product benefits:

- Protection against smelt and liquor splashes
- Inherently Flame resistant
- Very breathable
- Light weight
- Long lasting performance after washing

THANK YOU

PULP & PAPER

FLUE GAS COOLER

RECOVERY BOILER SERVICES

2022

ANDRITZ

ENGINEERED SUCCESS

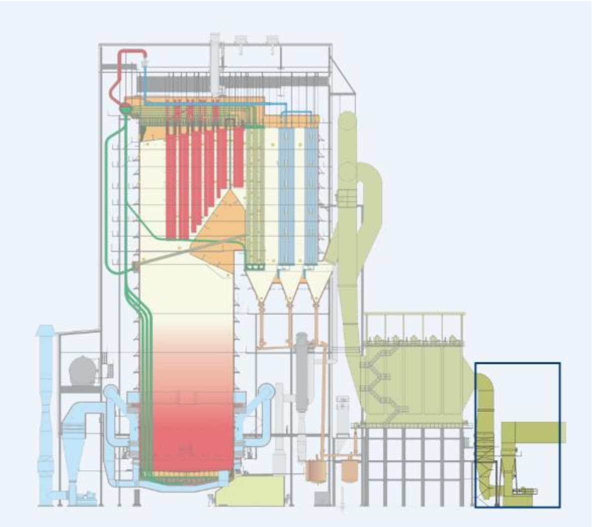
FLUE GAS COOLER

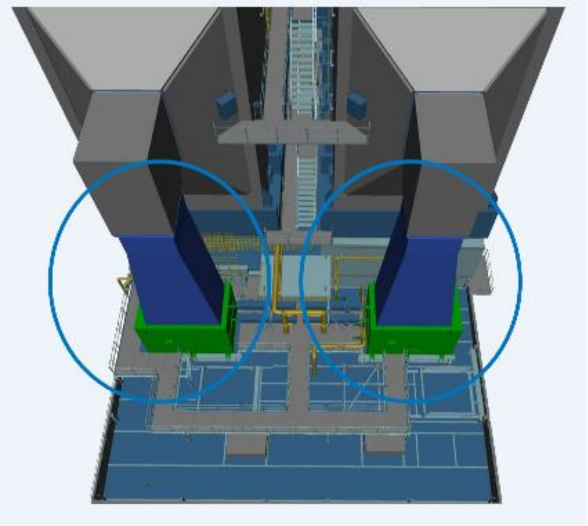
- The flue gas cooler system is a heat exchanger integral to the flue gas stream to extract additional heat from flue gases.
- The flue gas cooler can generate or supplement: **warm water, hot water, steam, and air**.

Optimize heat balance in the pulp mill

FLUE GAS COOLER

- Located after the electrostatic precipitator (ESP)
- Can easily be installed on existing boilers
  - *Enhance heat recovery and improve overall unit efficiency.*





HOW IT WORKS

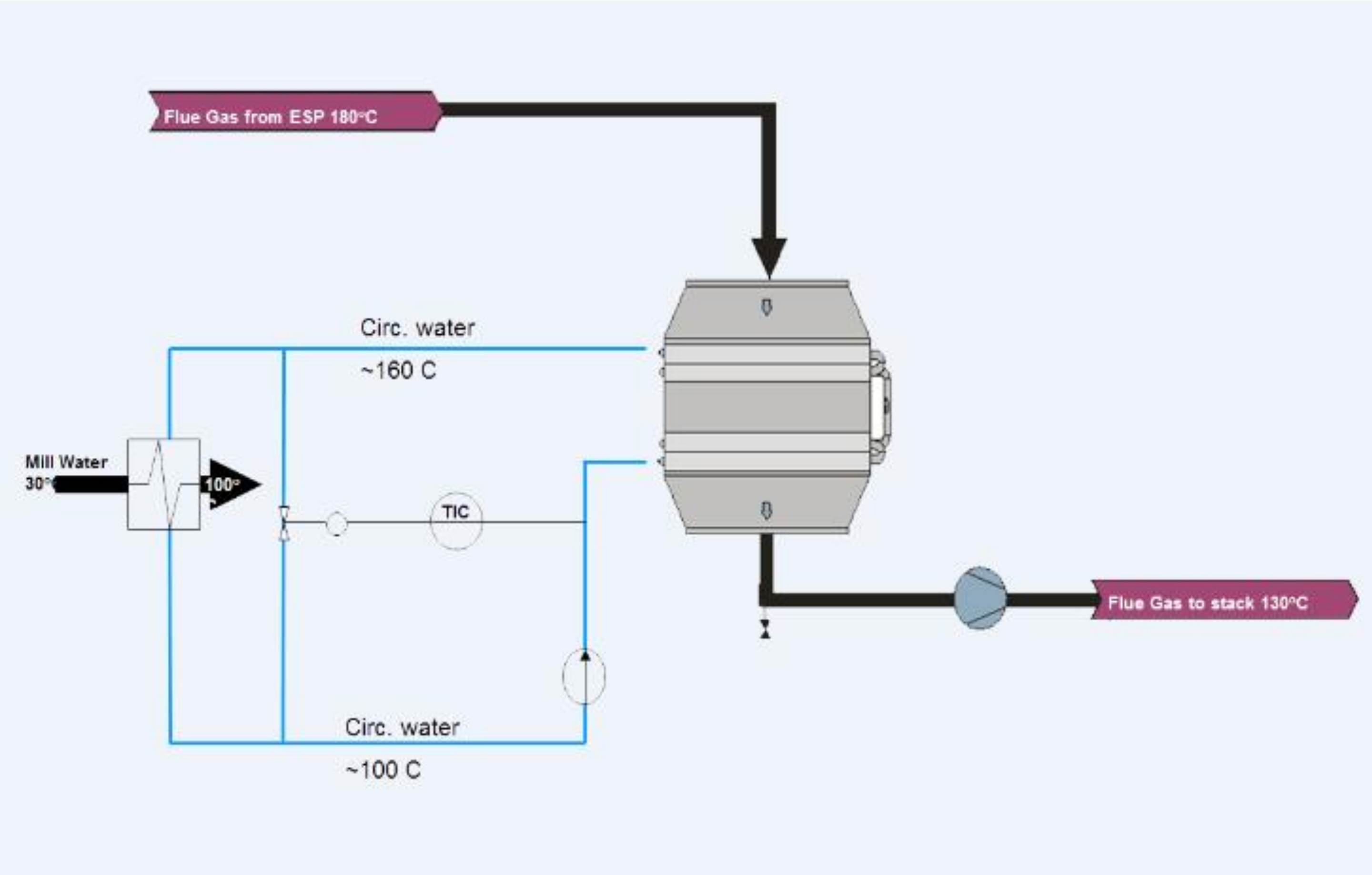
Flue gas cooler

The flue gas cooler is a carbon steel, finned tube heat exchanger with the following elements:

- Pressurized, closed-loop circuit
- Operating pressure normally 200 - 225 PSI
- Sootblowers used in each pass
- Low sootblower steam consumption due to the position downstream of the ESP

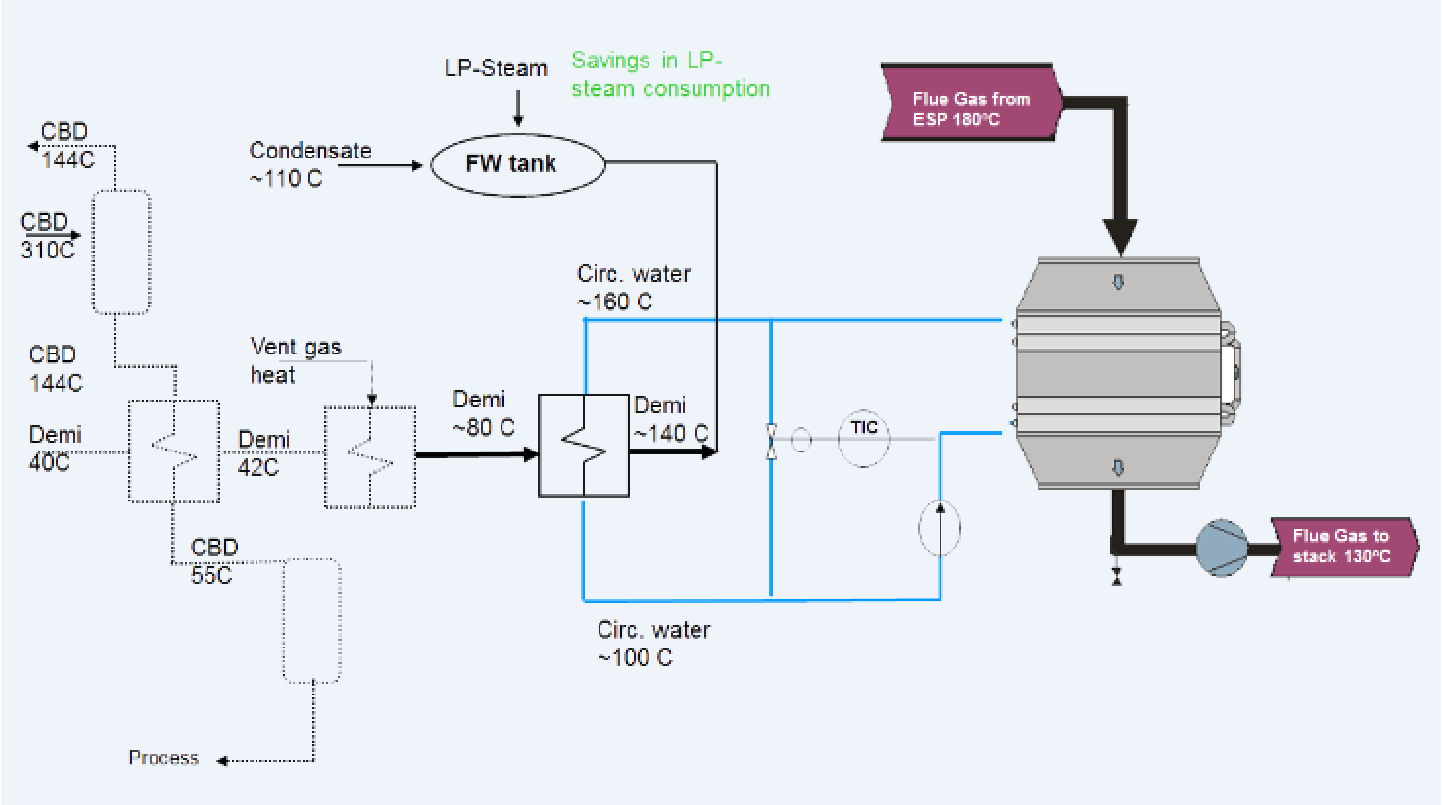
APPLICATIONS

Water Preheating



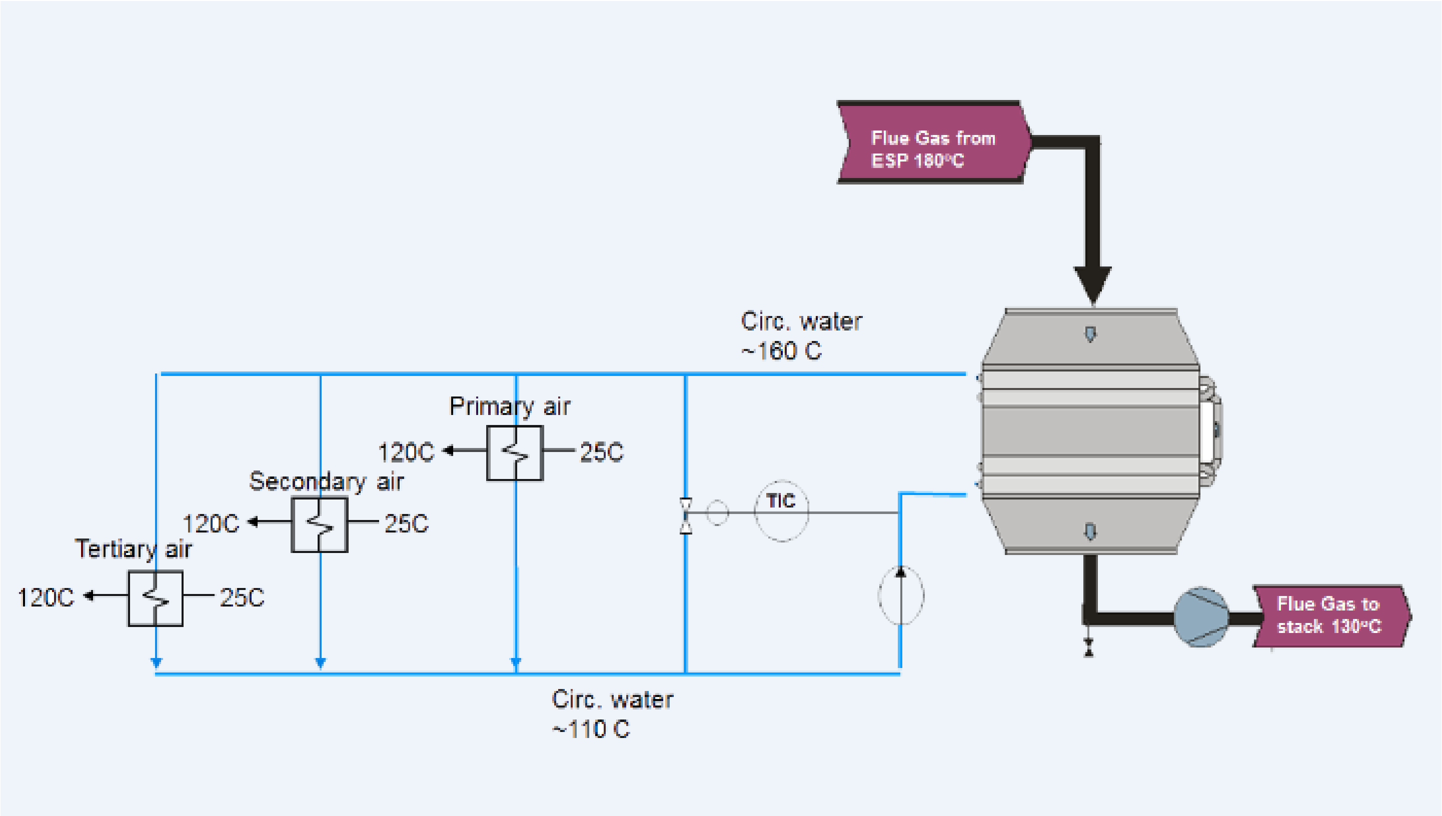
APPLICATIONS

Demi Water Heating



APPLICATIONS

Combustion Air Preheating



BENEFITS TO THE CUSTOMER

Flue gas cooler

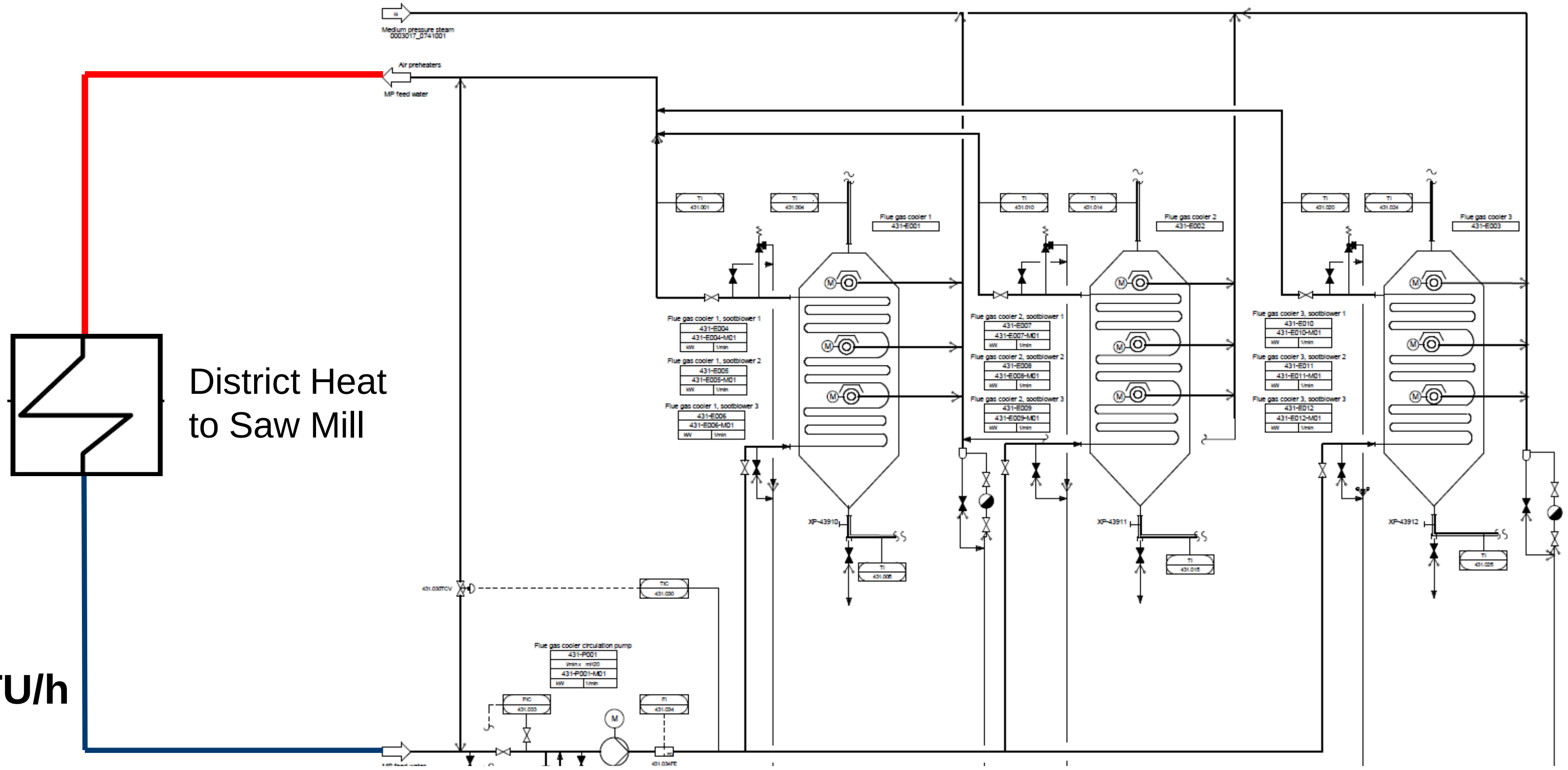
- Recover and use energy from flue gas
  - *Reduces auxiliary fuel consumption*
- Uniquely beneficial in situations with condensing turbines and high energy price
- Economical solution for heat recovery when seeking capacity upgrades
  - *Fast payback: 6 – 18 months*

MF RAUMA FGC

Case Study

MF Rauma:
3300 tDS/d;

- Flue gas
    - T In 356 °F
    - T Out 251 °F
- Circulation (Balance)
    - Flow 1.08 MMlb/h
    - T In 230 °F
    - T Out 277 °F
- Heat recovered **51 MMBTU/h**



RECOVERY BOILER REFERENCES

Flue Gas Cooling

- 25 total installations globally since 2006
    - Europe (9), Asia (11), South America (4), North America (1)
- 4 in 2021, 2 more slated for 2022 and 2023 startup

QUESTIONS?

Alec Shull, Product Manager – Smart Products for Recovery Boilers

alec.shull@andritz.com
706-344-9006

LEGAL DISCLAIMER

BABCOCK & WILCOX

RENEWABLE
ENVIRONMENTAL
THERMAL

Pulp Mill Steam Cycle Optimization

Steve Osborne, Technical Consultant
Greg Leibel, Sales Director, Pulp & Paper

AF&PA Recovery Boiler Conference
Atlanta, GA
February 2, 2022

What if you could

- Improve reliability
- Increase power generation
- Reduce purchased fuel costs
- Reduce greenhouse gas emissions

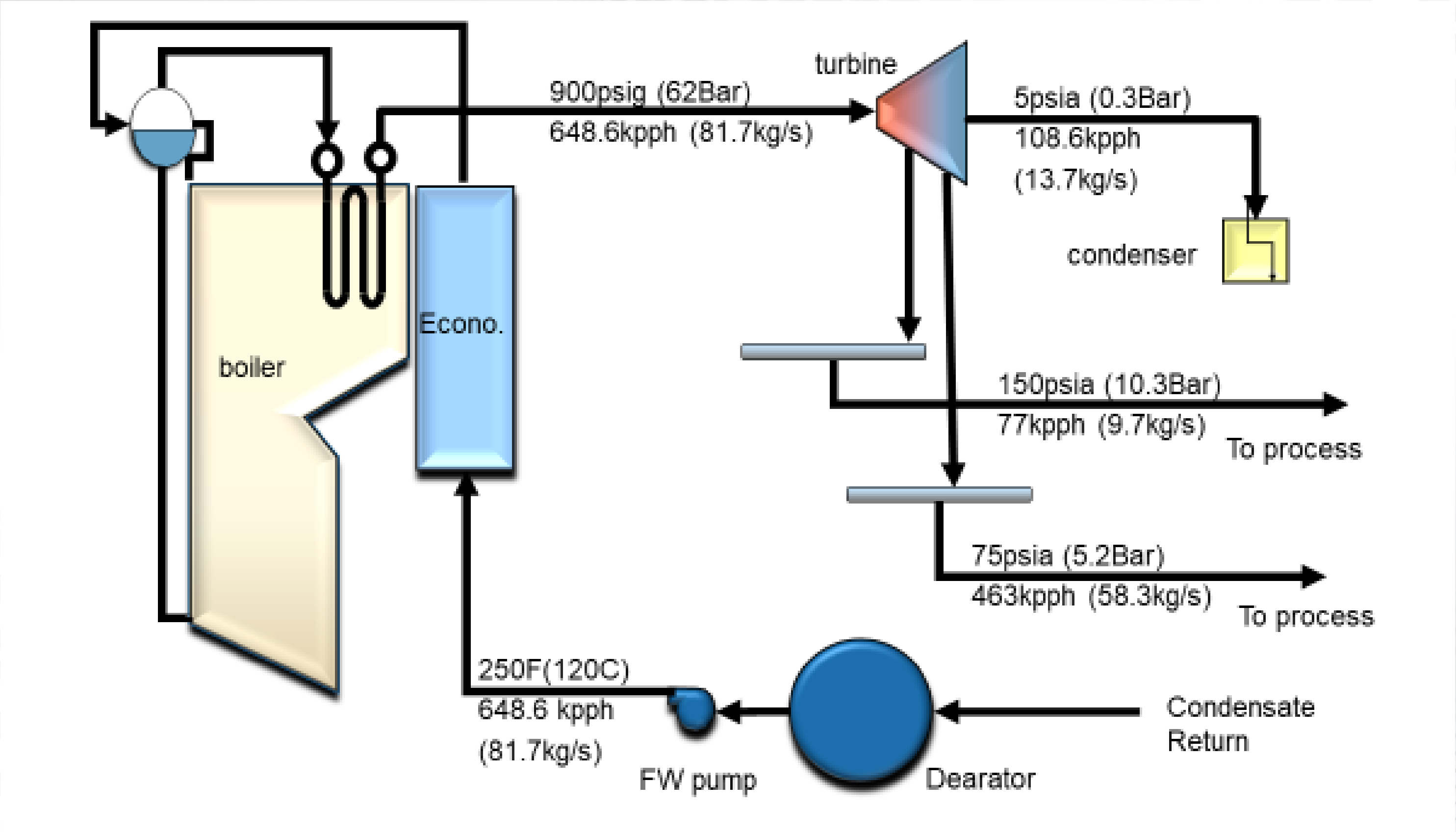
US Pulp Mills

- 34 Existing US pulp mills have multiple recovery boilers
- 19 of those 34 mills have recovery boiler operating pressure ≤ 900 psig
- Average mill capacity for these is 6.9 mlb/day DS

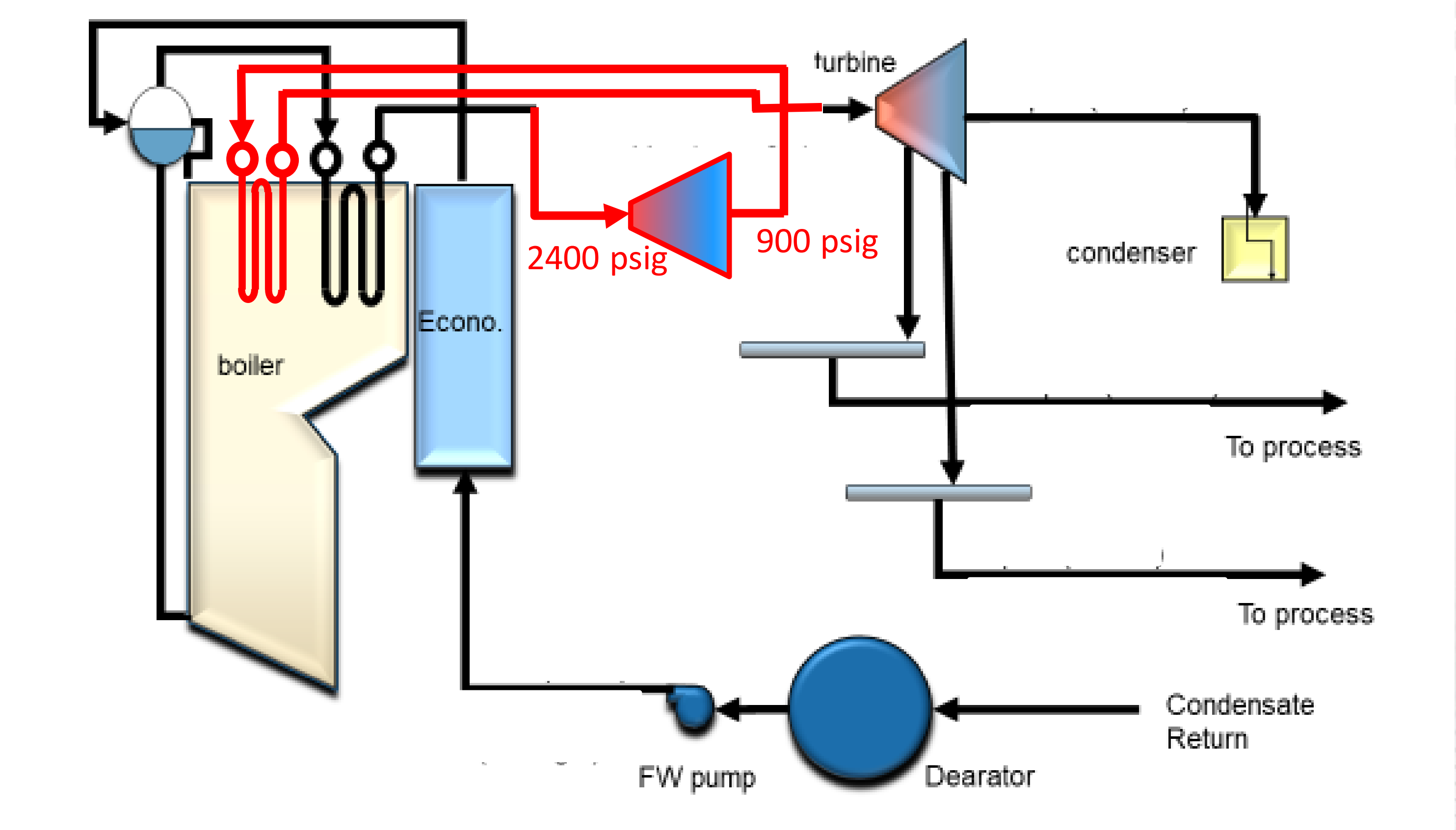
Here is How

- Replace existing boilers with a single high pressure boiler with reheat surface
- Add a high pressure turbine/generator
- Have the new turbine exhaust at existing main steam header pressure (+ line loss)
- Reheat the new turbine exhaust steam in the new boiler and send to existing turbine(s)

Typical 900psig (62Bar) Pulp Mill Steam Process



Adding 2400 psig to 900 psig cycle (simplified)



High Pressure Recovery Boiler Experience

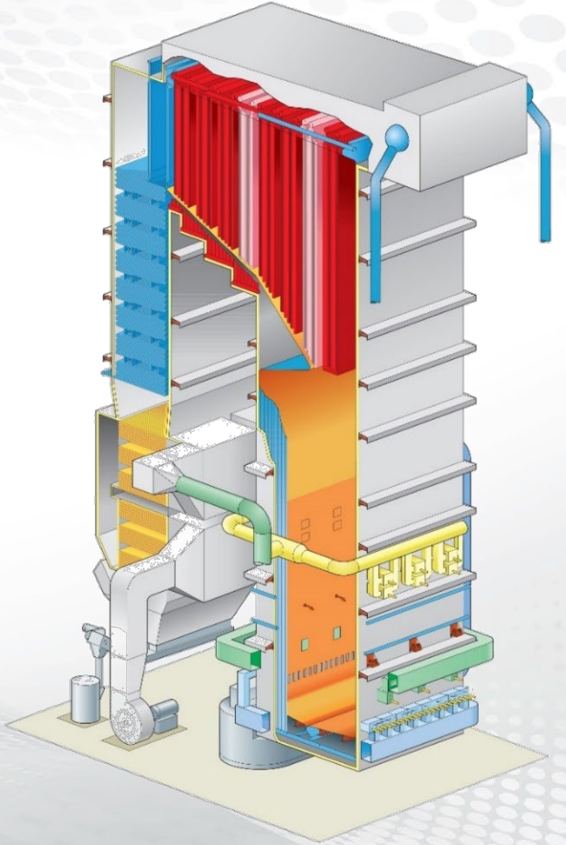
Of 48 North American operating boilers with design pressure ≥ 1250 psig

- B&W – 20 Oldest 61 years old
- Alstom – 10
- Valmet – 12
- Andritz – 6

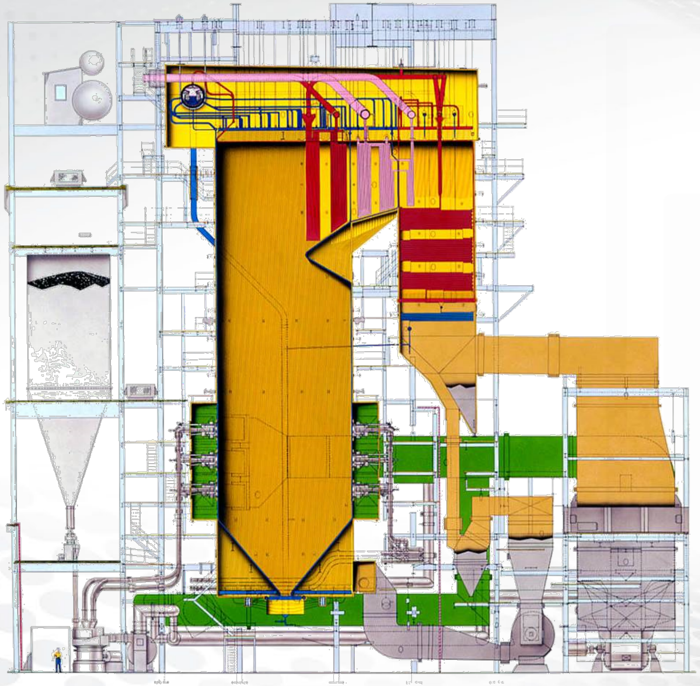
*BLRBAC data

B&W has more high pressure/ high temperature recovery boiler experience than any other boiler company

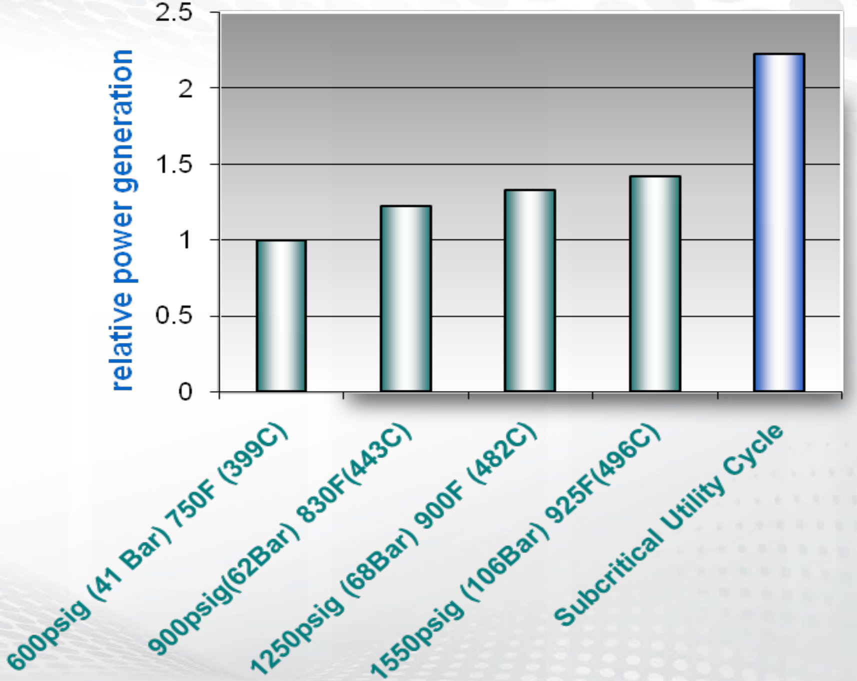
Plus hundreds of electric utility boilers



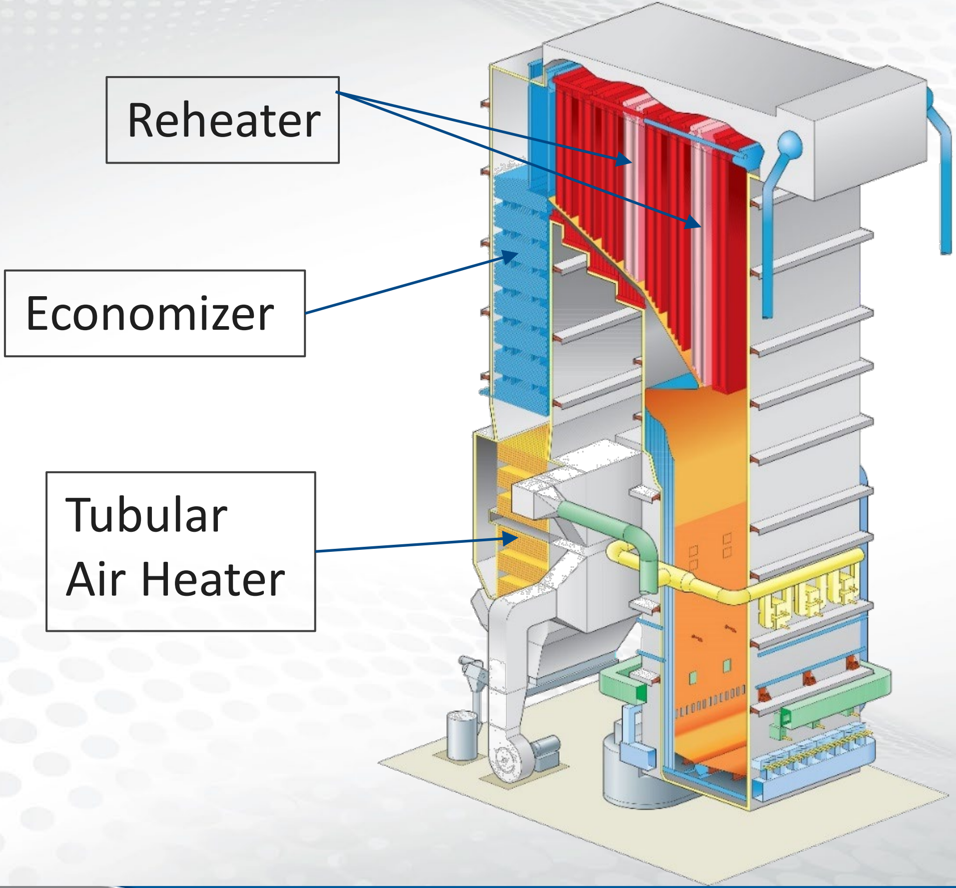
122 B&W Utility Boilers Supplied since 1980



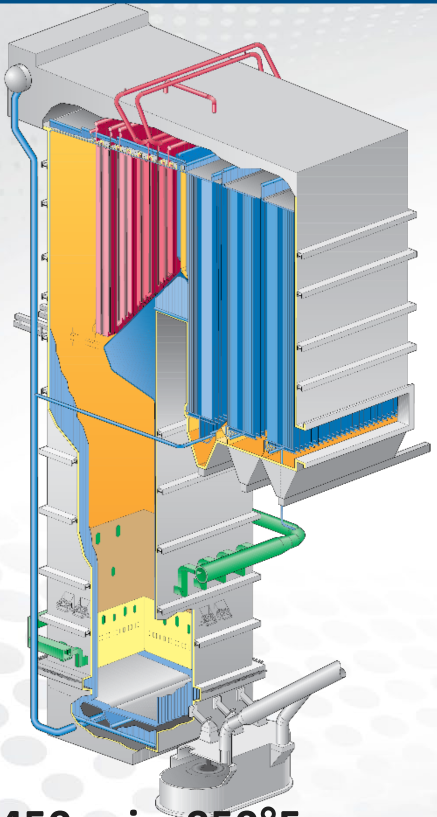
Natural circulation drum boiler pressures between 2400 and 2800 psig



High Pressure Recovery Boiler Design

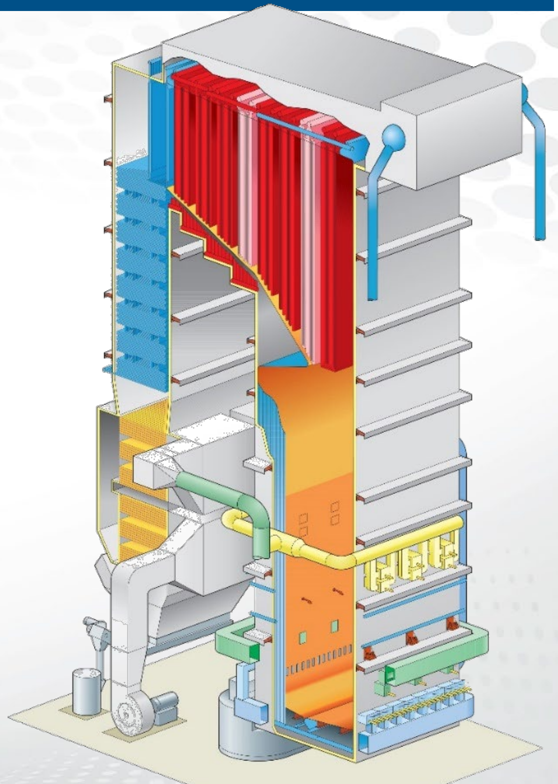


Heating Surface Comparison



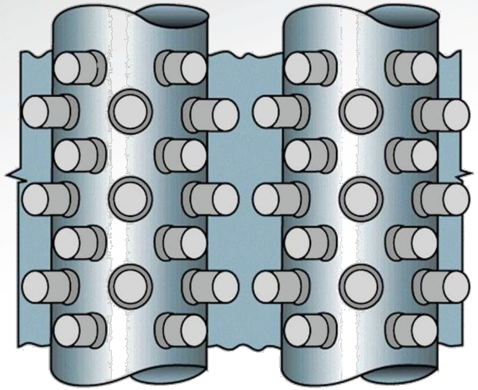
1450 psig, 950°F

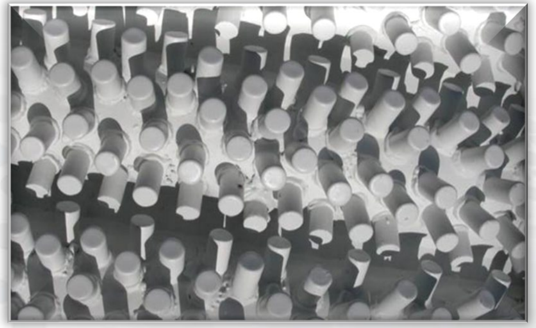
Superheater Banks	
5	6
Reheater Banks	
0	2
Generating Banks	
4	0
Furnace Size	
Same	Same
Economizer	
Same	Same*

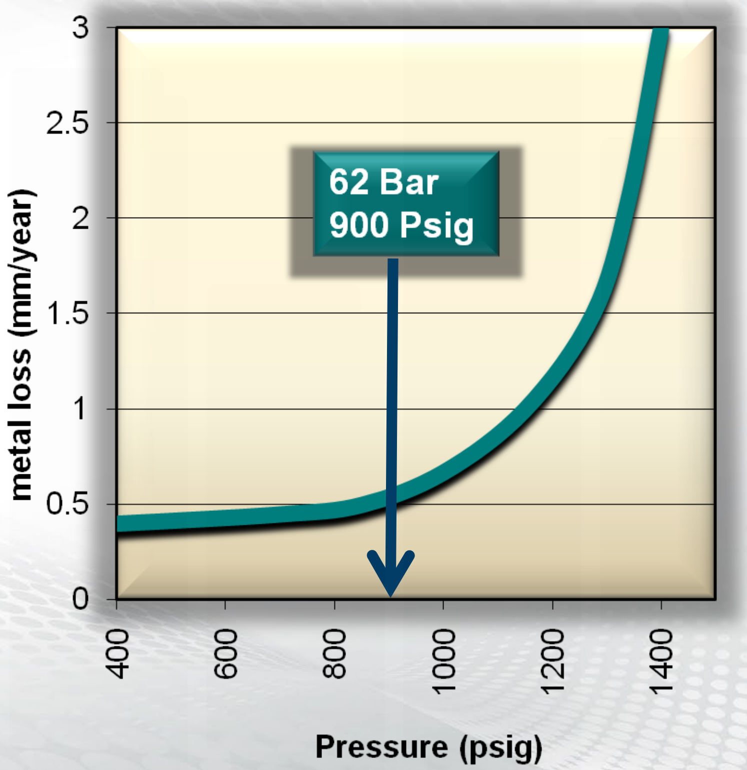


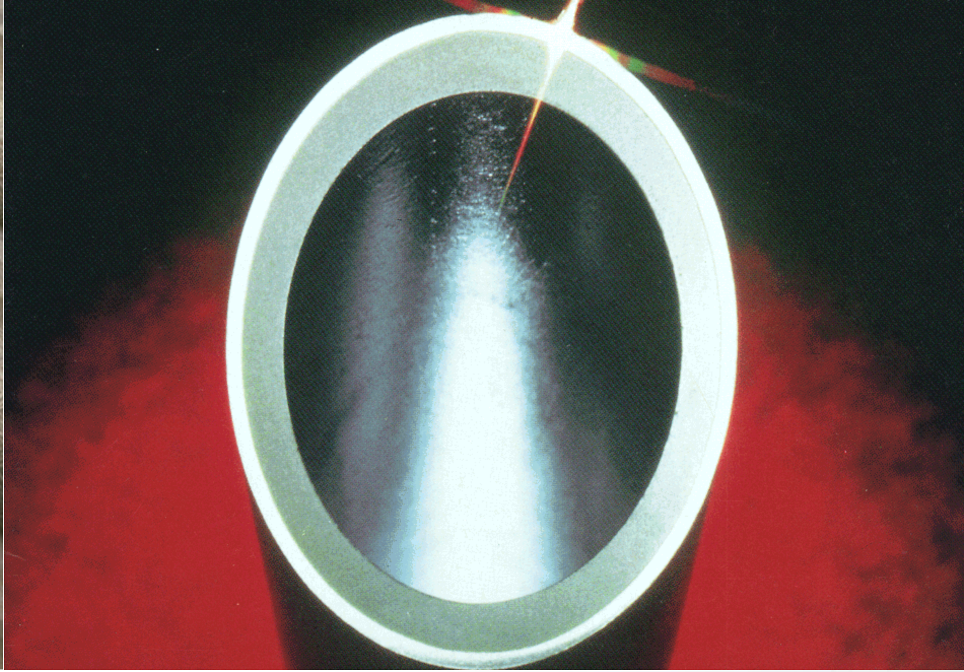
2400 psig, 950°F

Originally Only Carbon Steel Was Available







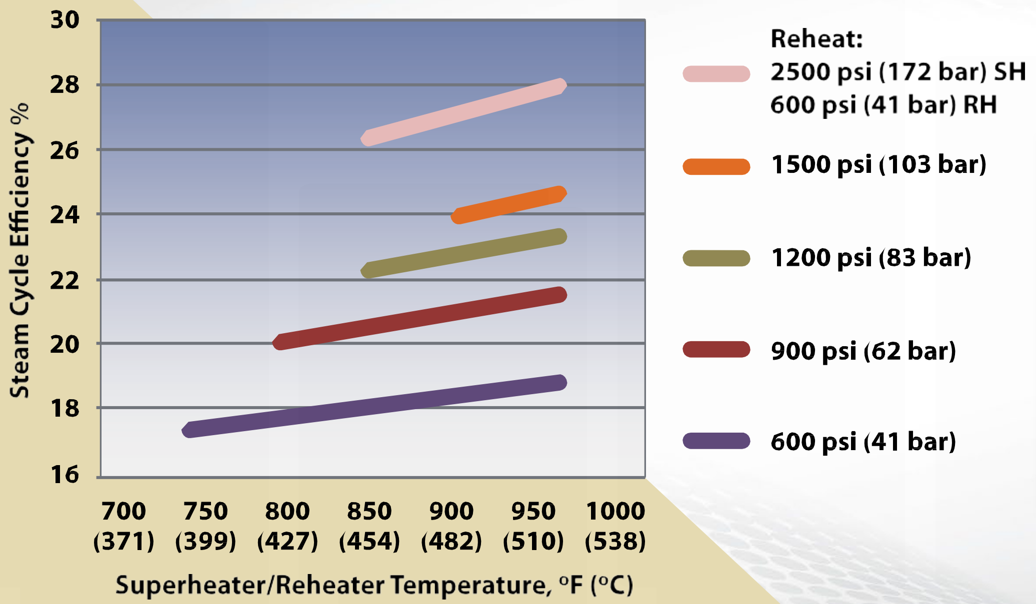


Inconel Coverage Allows Higher Design Pressures.

WOL provides more flexibility in core tube thickness than co-extruded tubing.

WOL allows the use of MLR tubing if needed

Benefit of Increased Steam Cycle Efficiency



Clean Energy at Lower Cost

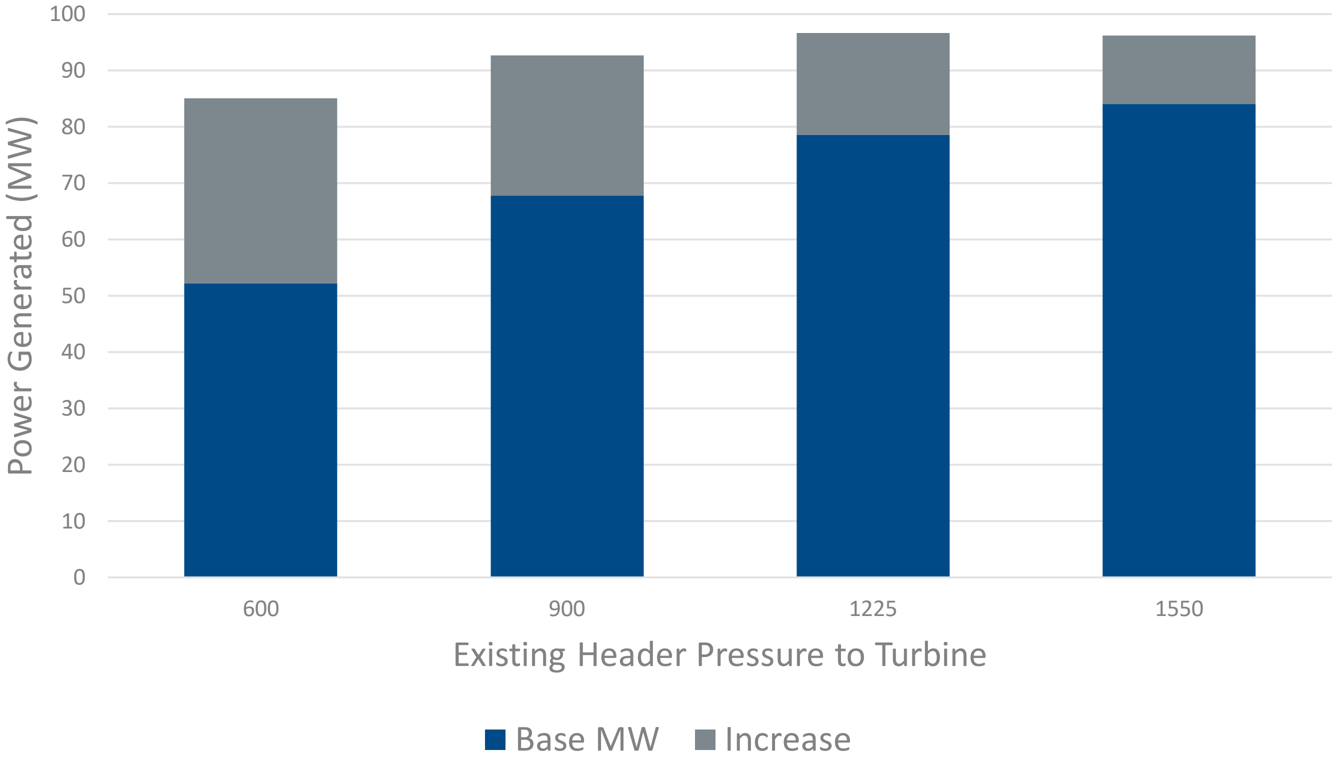
- 30 to 130% more power for the same fuel input
- Displace purchased fossil fuels
- Generate carbon credits
- Reduce carbon footprint
- Reduce emissions

Examples – matching RH w/existing cycle

Existing boiler Operating Conditions	600psig (41Bar) 750 F (399C)	900psig (62Bar) 830F (443C)	1225psig (84.5Bar) 900F (482C)	1550psig (106.8Bar) 925F (496C)
Cycle Efficiency %	16.3	20.0	22	23.5
Heat input for 1mk#/hr (126kg/s) steam	1160mkBTU/hr 339.9MWT	1192mkBTU/hr 349MWT	1220mkBTU/hr 357.5MWT	1224mkBTU/hr 358.7MWT
Power	52.2 MW	67.8 MW	78.6 MW	84 MW
New Operating Conditions	SH 2600psig (179Bar) 950 F (510C) RH 600 psig (41Bar) 750 F [illegible]	SH 2600psig (179Bar) 950 F (510C) RH 900psig (62Bar) 830 F(443C)	SH 2600psig (179Bar) 950 F (510C) RH 1225psig (84.5Bar) 900F (482C)	SH 2600psig (179Bar) 950 F (510C) RH 1550psig (106.8Bar) 925F [illegible]
Power	85.0 MW	92.7 MW	96.6MW	96.2 MW
Power Increase	[illegible]	24.9 MW	18 MW	[illegible]
New Cycle Efficiency	25.2%	26.5%	27%	26.9%
Change in Power Generation	163%	137%	123%	115%

Power Generation - Same Fuel Heat Input

adding 2600 psig "topping" turbine



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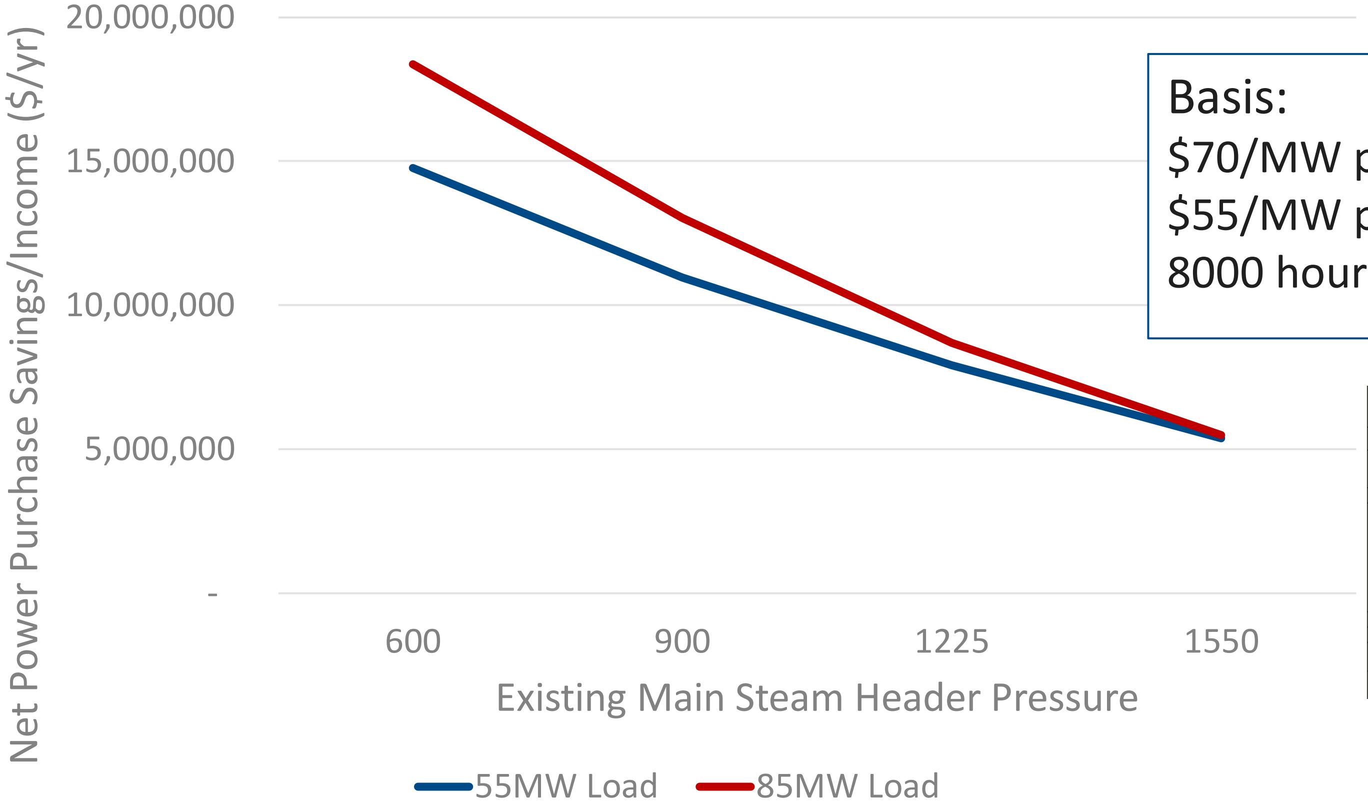
Cycle Efficiency %	16.3	20.0	22	23.5
Heat input for 1mk#/hr (126kg/s) steam	1160mkBTU/hr 339.9MWT	1192mkBTU/hr [illegible]	1220mkBTU/hr [illegible]	1224mkBTU/hr 358.7MWT
Power	52.2 MW	67.8 MW	78.6 MW	84 MW
New Operating Conditions	2600psig (179Bar) 950 F (510C) RH 600 psig (41Bar) [illegible]	[illegible] 2600psig (179Bar) 950 F (510C) RH 900psig (62Bar) [illegible]	[illegible] 2600psig (179Bar) 950 F (510C) RH 1225psig (84.5Bar) [illegible]	2600psig (179Bar) 950 F (510C) RH 1550psig (106.8Bar)
Power	85.0 MW	92.7 MW	96.6MW	96.2 MW
Power Increase	[illegible]	[illegible]	[illegible]	[illegible]
New Cycle Efficiency	25.2%	26.5%	27%	26.9%
Change in Power Generation	163%	137%	123%	115%

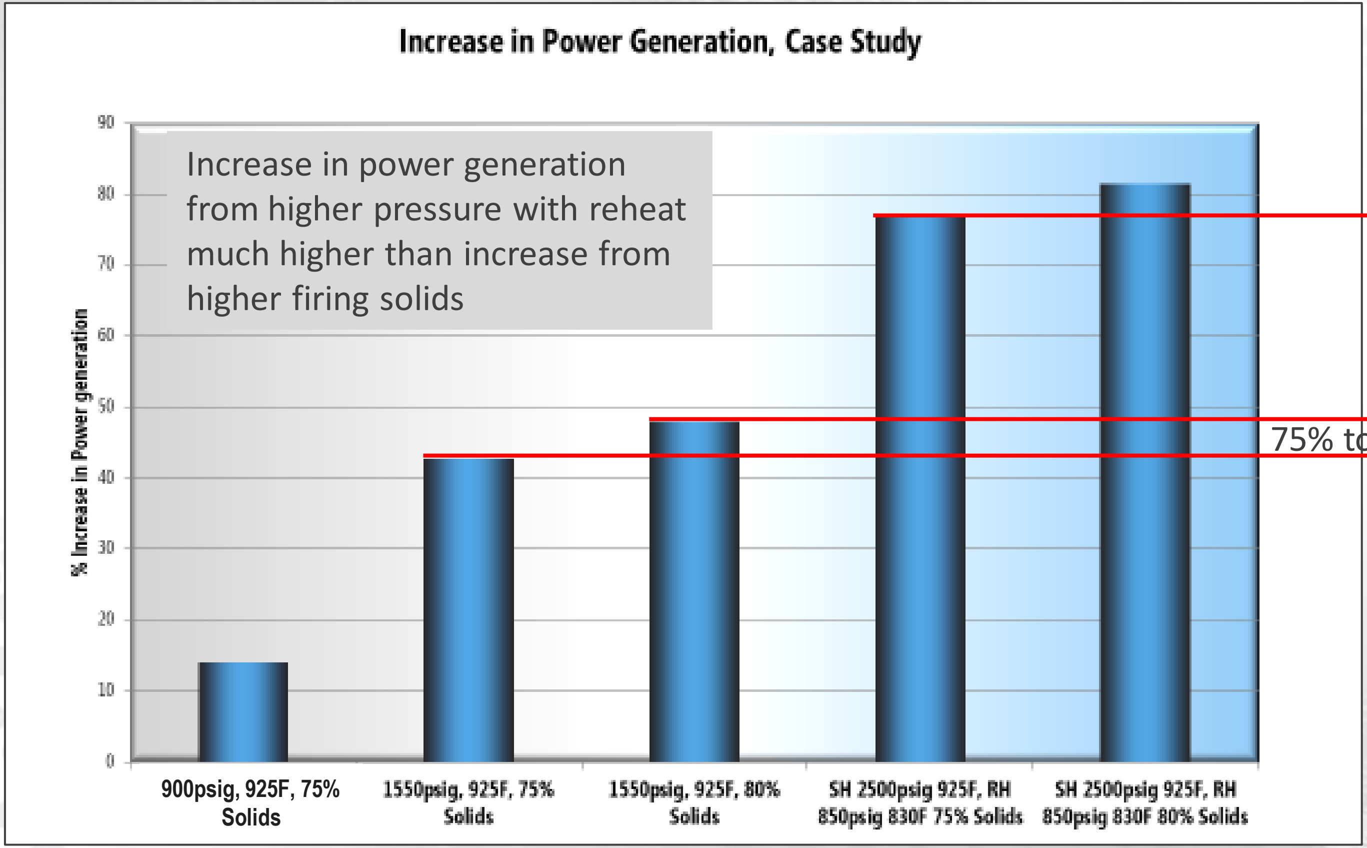
Net Return on Purchased/Sold Electricity



Basis:
$70/MW purchased power
$55/MW power sales
8000 hours/year

Existing boiler Operating Conditions	600psig (41Bar) 750 F (399C)	900psig (62Bar) 830F (443C)	1225psig (84.5Bar) 900F (482C)	1550psig (106.8Bar) 925F (496C)
Cycle Efficiency %	16.3	20.0	22	23.5
Heat input for 1mk#/hr (126kg/s) steam	1160mkBTU/hr 339.9MWT	1192mkBTU/hr [illegible]	1220mkBTU/hr [illegible]	1224mkBTU/hr 358.7MWT
Power	52.2 MW	67.8 MW	78.6 MW	84 MW
New Operating Conditions	2600psig (179Bar) 950 F (510C) RH 600 psig (41Bar) [illegible]	[illegible] 2600psig (179Bar) 950 F (510C) RH 900psig (62Bar) [illegible]	[illegible] 2600psig (179Bar) 950 F (510C) RH 1225psig (84.5Bar) [illegible]	2600psig (179Bar) 950 F (510C) RH 1550psig (106.8Bar)
Power	85.0 MW	92.7 MW	96.6MW	96.2 MW
Power Increase	[illegible]	[illegible]	[illegible]	[illegible]
New Cycle Efficiency	25.2%	26.5%	27%	26.9%
Change in Power Generation	163%	137%	123%	115%

Power Generation Increase



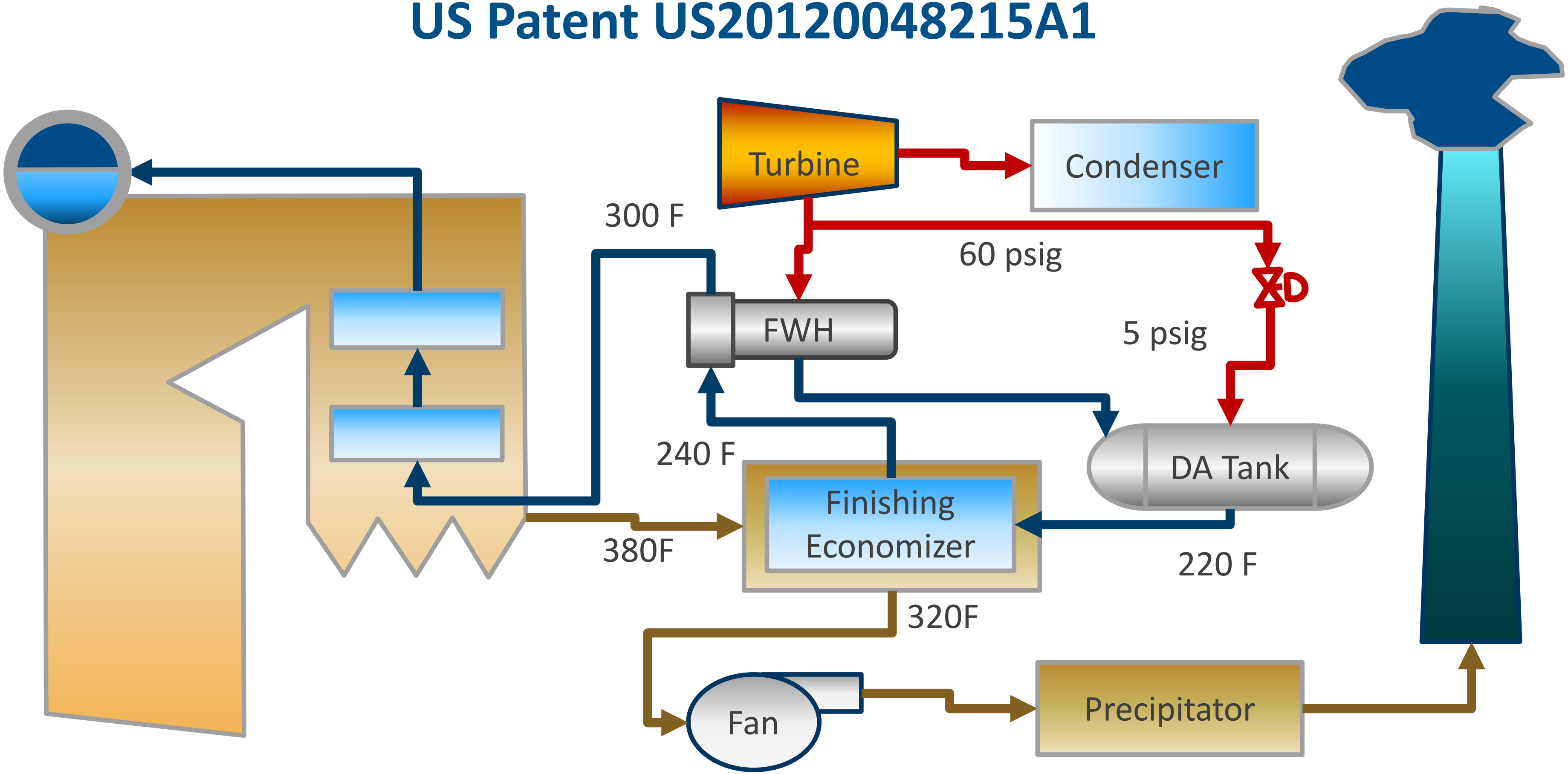
1550psig, 925F to 2500psig, 925F w/RH – both at 75% solids

75% to 80% solids

Retrofit Options for Efficiency Improvements

- Finishing Economizer
- Water Coil Air Heaters (WCAH)
- Split Stream Economizer

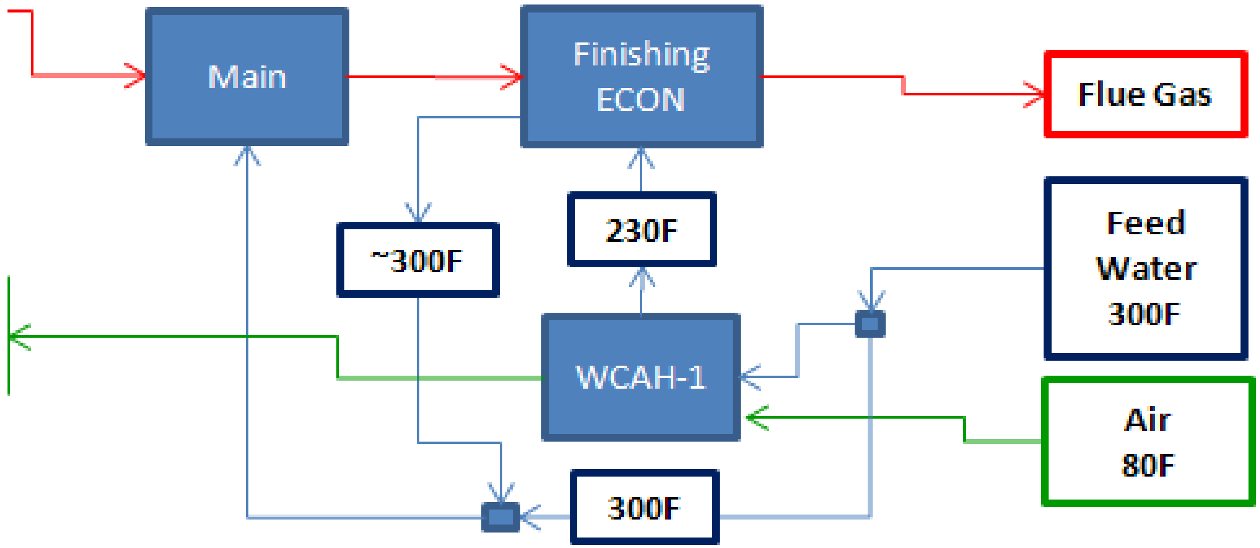
Finishing Economizer
US Patent US20120048215A1



Split Stream Economizer

What is a split stream economizer?

A system that utilizes a combination of water coil air heaters and economizer surface to heat combustion air while lowering unit exit gas temperatures to specified levels.



BABCOCK & WILCOX

RENEWABLE

ENVIRONMENTAL

THERMAL

Pulp Mill Steam Cycle Optimization

THANK YOU!

QUESTIONS?

Improvements to the Recovery Boiler Camera & Best Practices

Agenda

Improvements to the Recovery Boiler Camera and Best Practices

1. Brief Overview
2. Common Customer Issues
3. Product Improvements
4. Camera Locations
5. Best Practices for Reliability

Valmet Smelt Bed Cameras North America

Installations

- 90 smelt bed camera installations
- 65/173 recovery boilers
- 43 mills
- Other applications
  - RB upper furnace monitoring
  - Lime kiln monitoring (Visible)
  - BFB
  - Bark/Waste Boilers (IR and visible)
  - Inspection Camera

History

- Over 20 years of recovery boiler monitoring
- First installation was in 1999 (Enertechnix)
- Valmet acquired Enertechnix in 2018

Customer Camera Issues

Customer Camera Issues

Original Design

- Insertion/Retraction Frame
  - Camera sticks
  - Camera sometimes unstable when retracting
  - Frequent camera cradle replacements
- Port Rodder/Cleaner
  - Frequent air cylinder replacement
  - Unsuccessful port rodding cycles
  - Salt cake build up on camera lens and register
- Camera Lens
  - Degraded image quality on the longer lenses (insertion depths over 44")
  - Gets dirty frequently
- Air Consumption
  - 110scfm
- Control Boxes
  - Frequent solenoid valve replacement
  - Hard to service

Original Design

Product Improvements

Upgraded Auto-Retract Cylinder

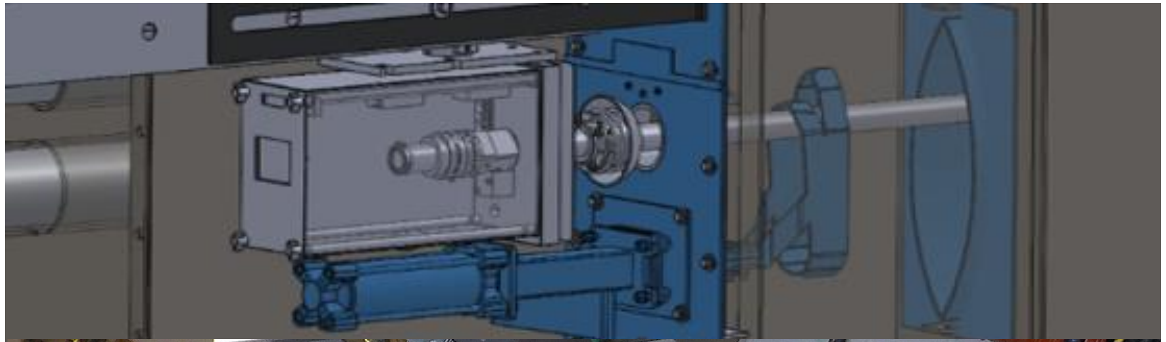
Original

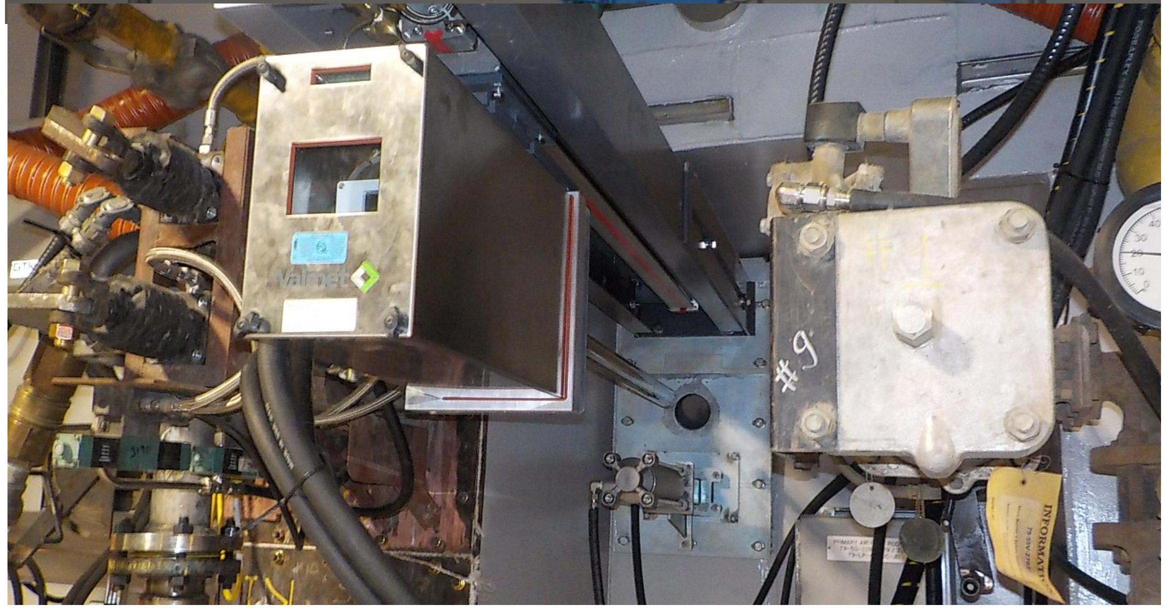
- External Adjustable Key Guide

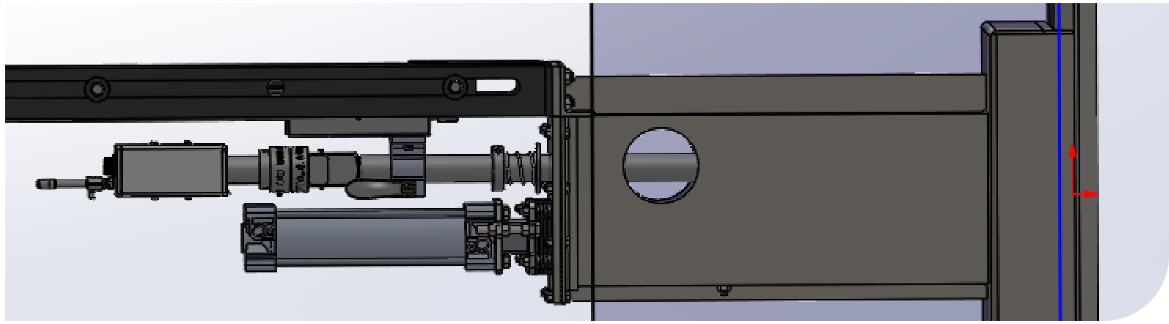
Upgraded

- Precision Roller Guide
- Smooth camera insertion and retraction
- Higher load capacity
- Very Stable

Improved Port Rodder and Camera Register





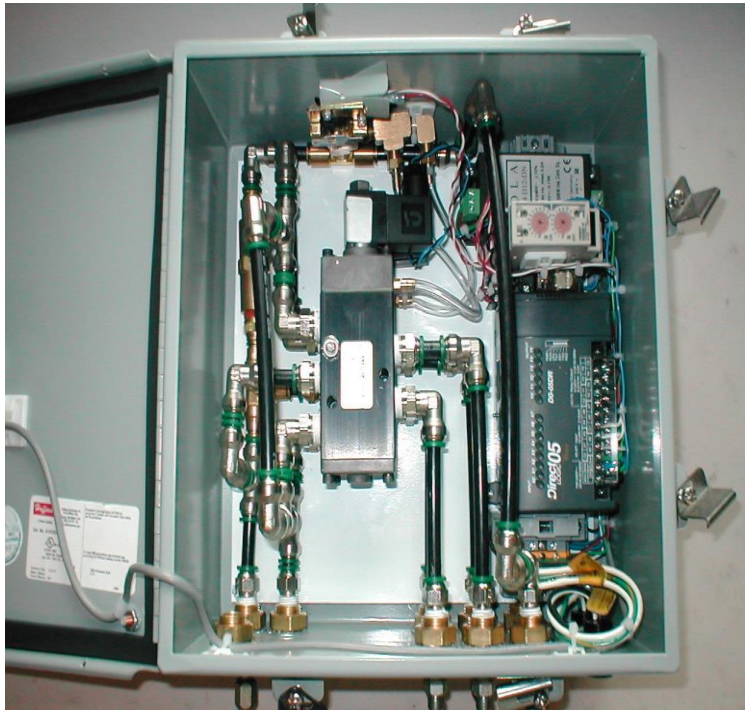


- Integrated air camera register
- Positive air pressure keeps port and register cleaner
- Custom cleaner head to match port size and port shape (cookie cutter)
- Better quality pneumatic cylinder
- Fewer repairs
- Easier to service and make repairs

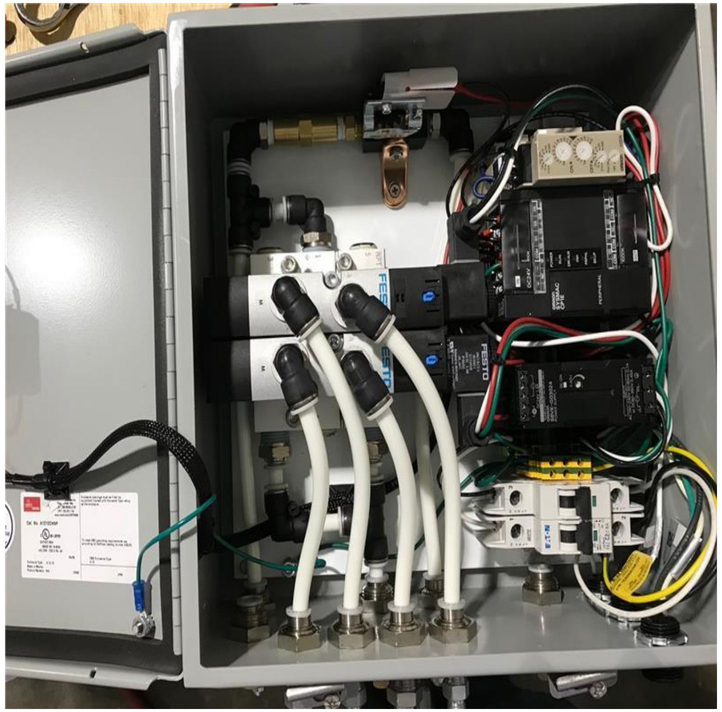
New Style Control Boxes

- Better Quality Components
- PLC allows for future upgrades
- Modular design
- Easier to service
- More reliable solenoid valves

Old Control Box



New Control Box

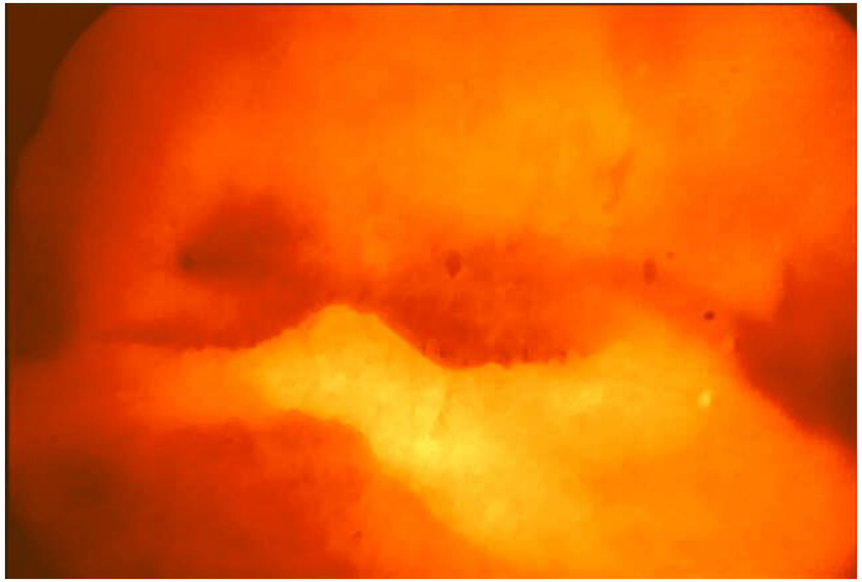


New High-Performance Lens

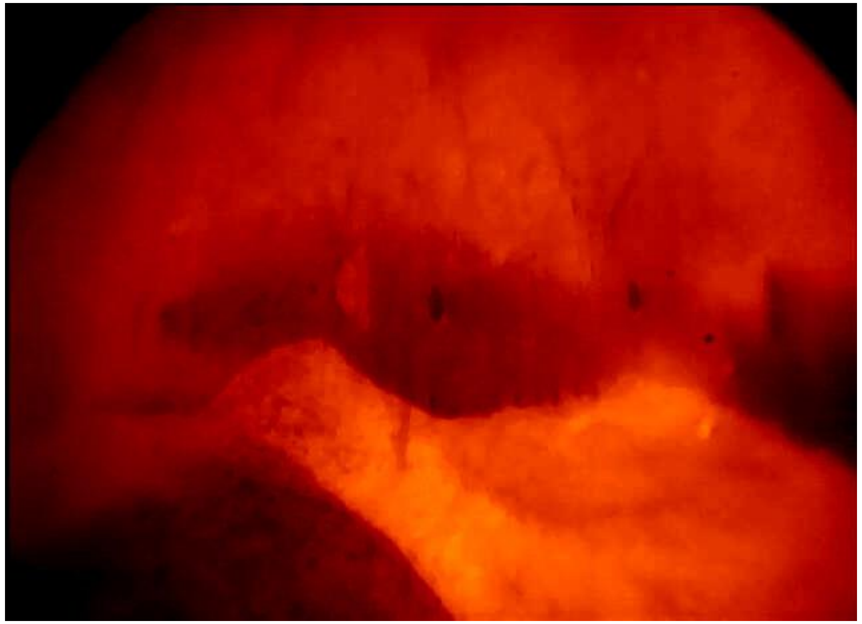
Benefits

- Wider range of focus
  - Improved Image Quality
- Image quality improvement on lens tubes over 58” (wind box > 44”)
  - 66” Tube
  - 72” Tubes
- Cross Flow Design
  - Significant reduction in air consumption from 110scfm to 60scfm @60psi
  - Lower operating costs
  - Improved lens tip air-flow reduces need for cleaning

A



B

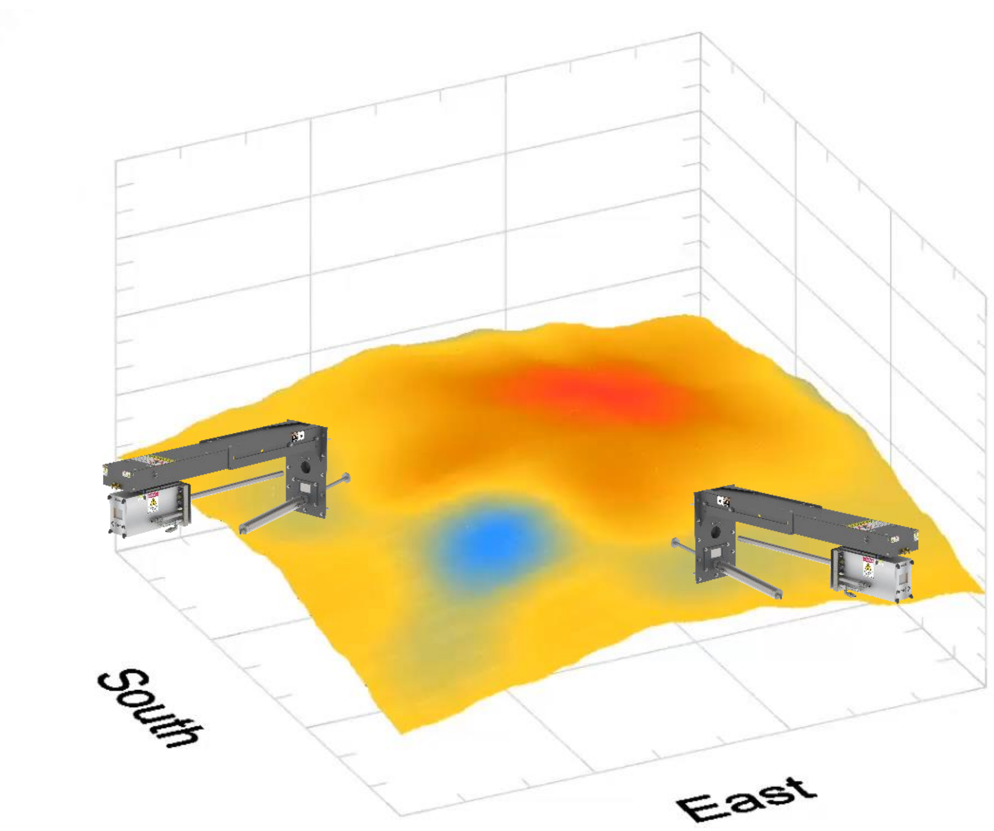


A: Standard Lens

B: High Performance Lens

3D Bed Profiling Software (Pilot)

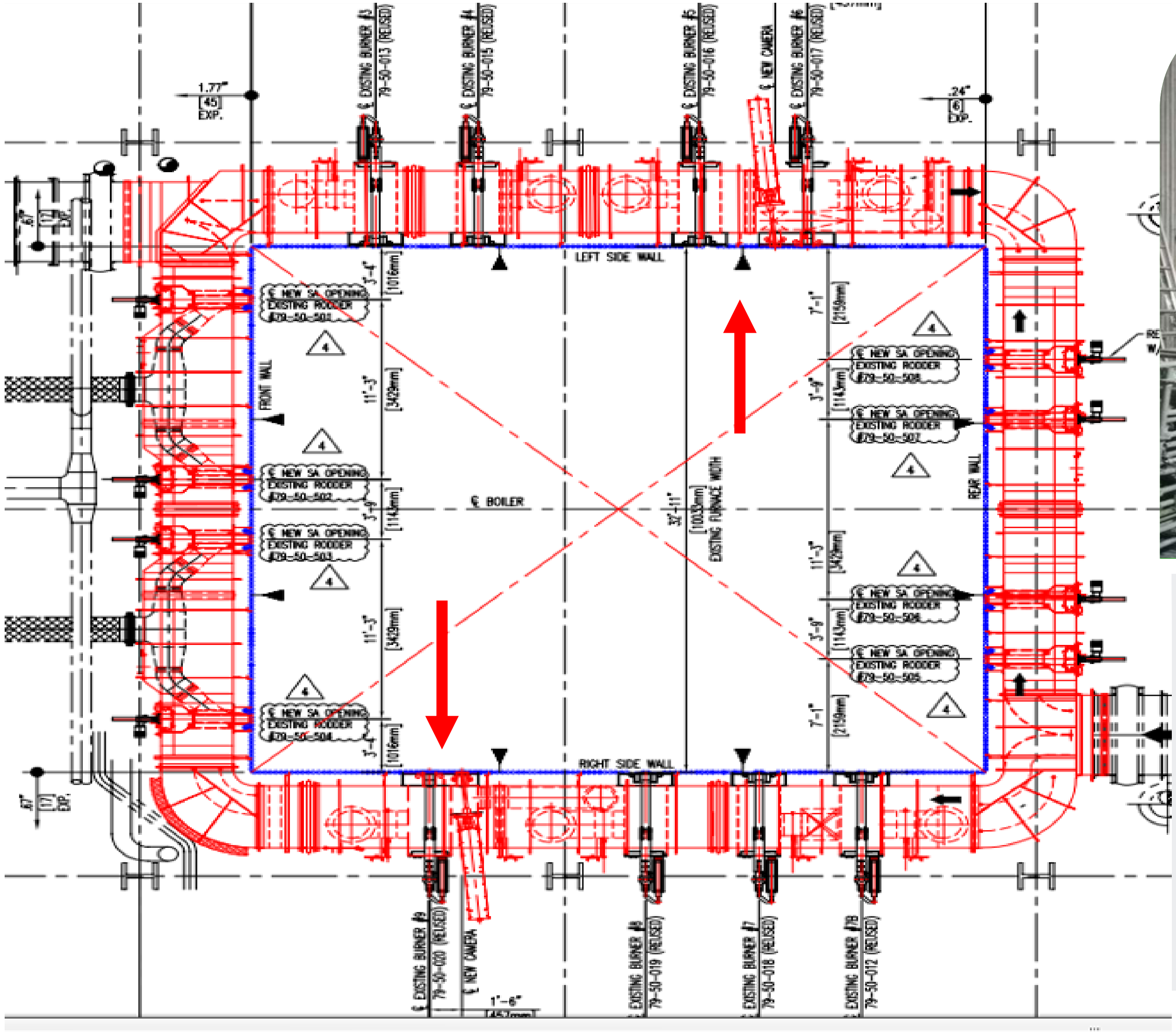
- Application Description: Utilize two 120° FOV Valmet Furnace Imaging Systems mounted on perpendicular walls of a recovery boiler at the secondary air level to determine edge profiles which (when combined) can be used to calculate volume
- Project Goal: Provide a repeatable volume measurement of the char bed in recovery boilers and supply the required data to meet the needs of the APC

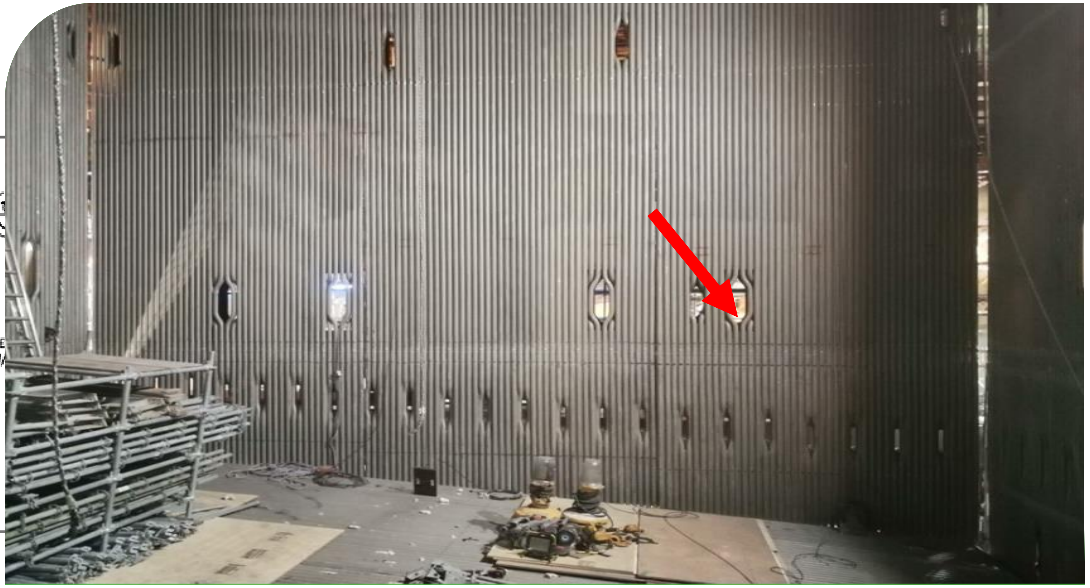


Camera Location

Installation Example

North and South Walls



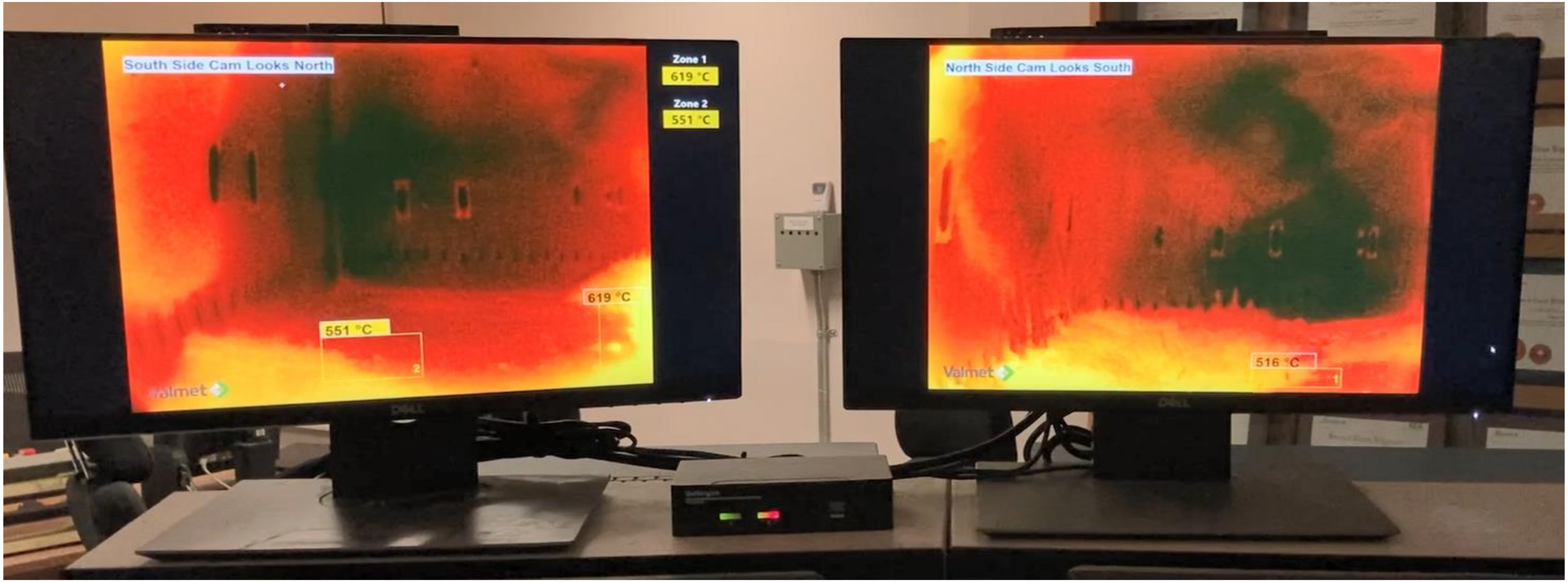


- Cameras are located near corners to maximize 120° field of view
- Located on secondary air level
- Cameras are looking north and south
- Camera location is dependent on boiler size
- Avoid installing above spout decks

Valmet

Installation Example

Control Room View



South Camera

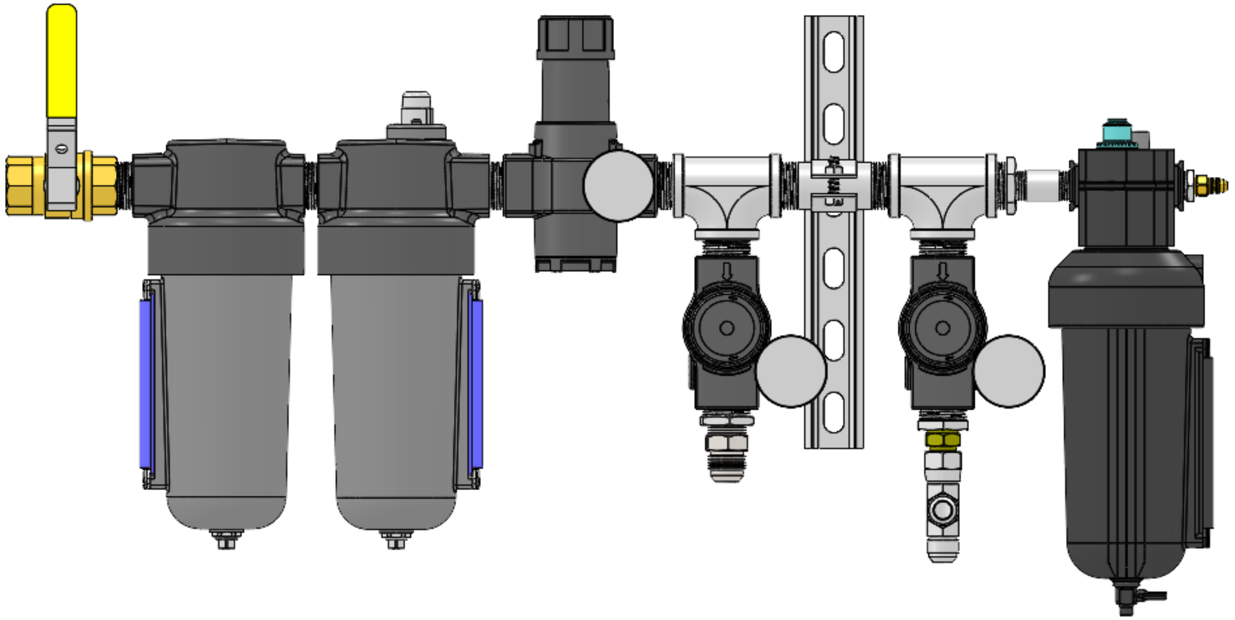
North Camera

Best Practices

Best Practices

Typical Camera Failures and Causes

- Electrical components over-heating
  - Inadequate cooling air
- Lens damage
  - Inadequate cooling air
  - Quality of compressed air (water, rust, oil)
  - Lack of PM schedule
- Solenoid valve failure
  - Quality of compressed air
  - Lack of PM schedule
- Burnt up lens
  - Solenoid failure for Auto Retraction during air loss event
  - Air loss event (rail mounted, no retract)



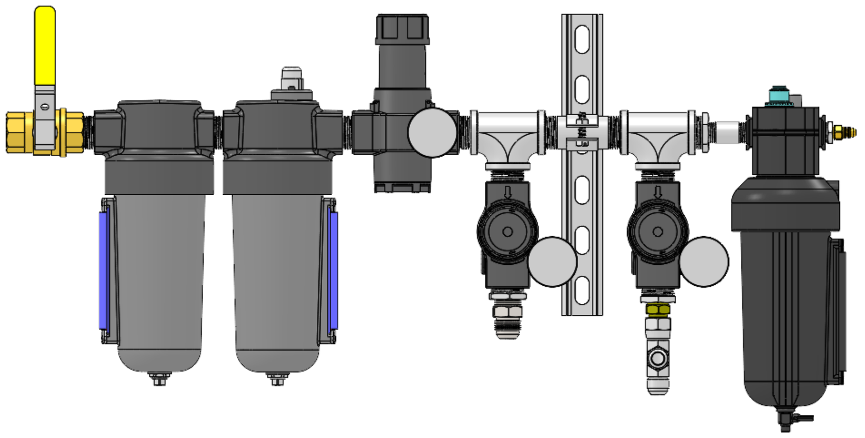
The Common Denominator = Air Quality

Best Practices

Mill PM Schedule

- Inspect air system
  - Air pressure @60psi
  - Verify cooling air in enclosure and lens purge
  - Inspect hoses for leaks
  - Tighten all hose connections
  - Check filter elements and replace if needed
  - Fill lubricator to fill line
- Verify all mechanical functions
  - Insert/Retract
  - Loss of air retract
  - Port Cleaner Cycling
- Inspect integrity of structure
  - Verify Insertion Depth
  - Verify all bolts are tight
  - Inspect port cleaner hardware

- Confirm image quality in control room
  - Get operators feedback and make any adjustments
- Call Valmet as immediately as possible if cameras require service or parts are needed



Best Practices

Long Term Reliability

- Valmet Service Agreement
- Mill PM Schedule
- Upgrades
  - Crossflow Lenses
  - Control Box
  - Auto-Retract air cylinder
  - New Style Concentric Port Cleaner
  - Latest Generation Imaging Module
    - Gen 1 and 2 are obsolete and cannot be repaired
  - Analog to Digital
    - Less failure points
- Valmet Remote Access
  - Trouble shoot with operators

- Spare Parts Inventory
  - Imaging Module
  - Axis Server
  - Computer
  - Lens Tube Assembly
  - Electronics Tray for Enclosure
  - Lens Tip
  - Field Lens
  - Relay Lens
  - Filter Elements

Summary

- Customer issues with smelt bed cameras
- Product improvements to reduce issues
  - Auto Retract Cylinder/Cradle
  - Camera Port Rodder/Cleaner
  - Camera Air Register
  - Control Boxes
  - High Performance Lens
- Best Practices
  - Camera location
  - Camera failures and causes
  - Mill PM schedule
  - What’s needed for camera reliability

- Questions?

- Thank you for your time!!

Valmet Boiler Diagnostic Systems

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Valmet FORWARD

Recovery Ash Analyzer and Ash Balance Advisor

Travis Conner

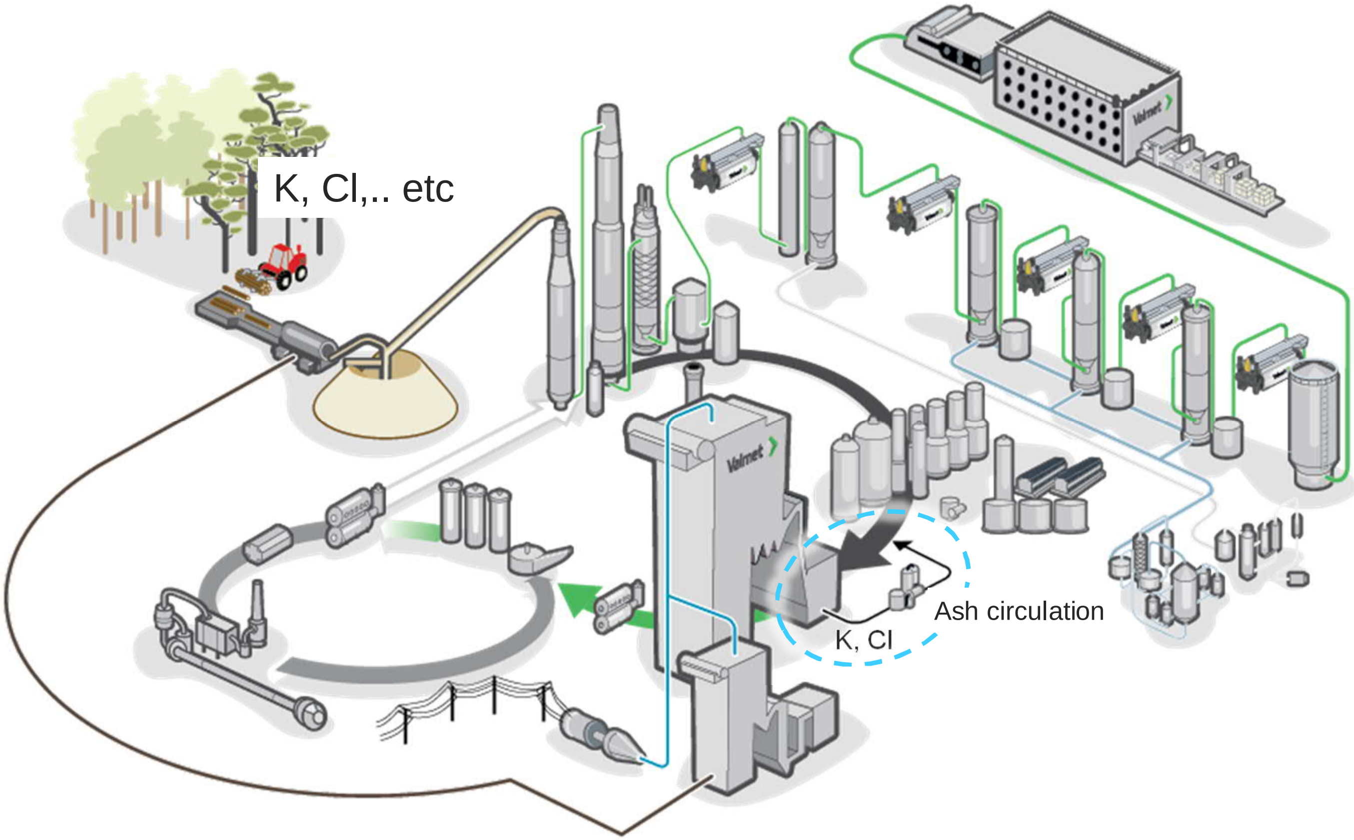
Recovery Solution Manager

Valmet North America Automation

Contents

Recovery boiler ash circulation

Chemical recovery of recovery boiler

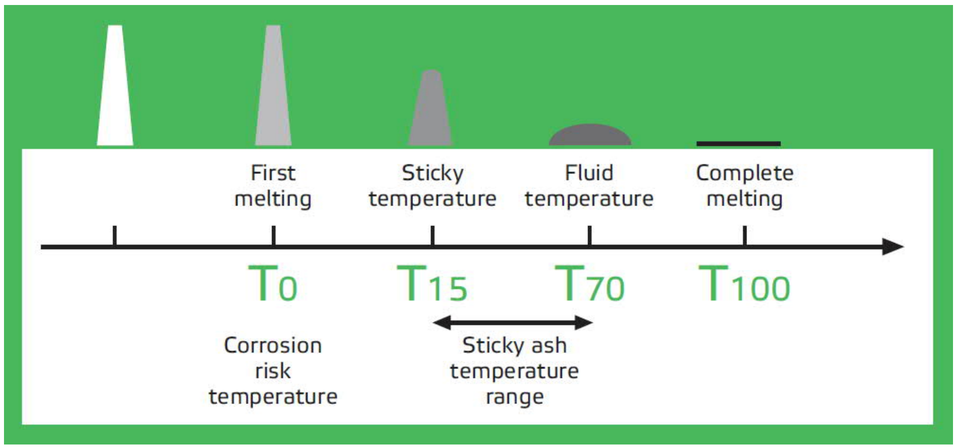


Combustion of black liquor generate large amount of ash, which contains valuable cooking chemicals. Ash is further circulated back to combustion liquor.

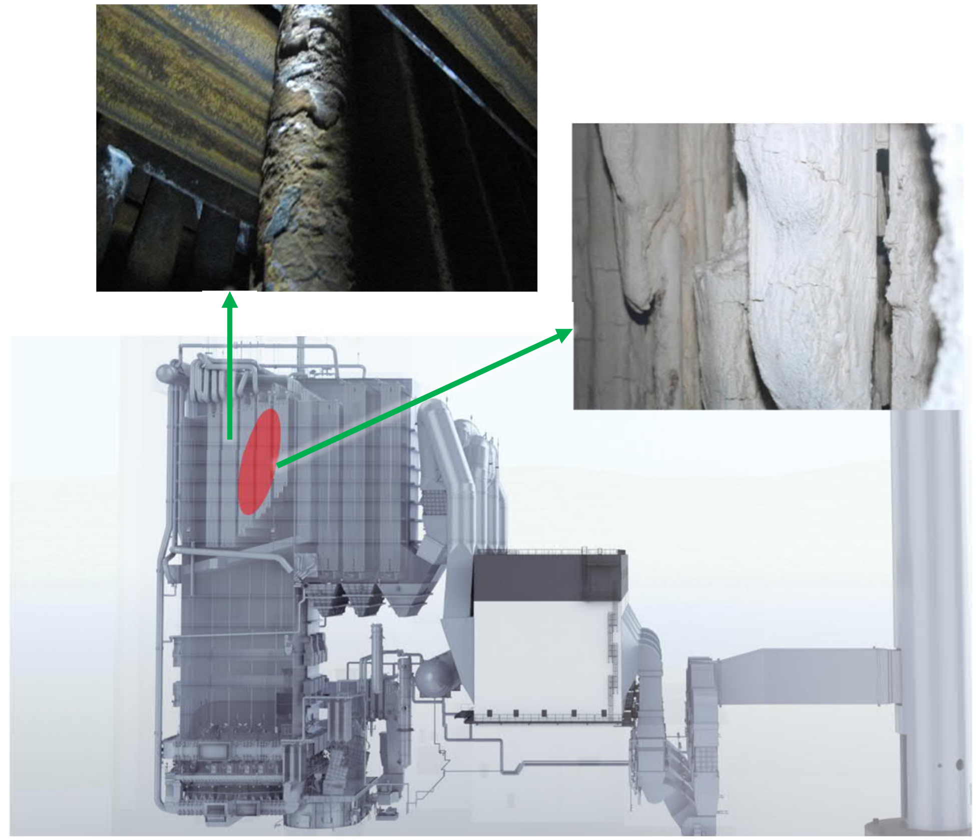
This circulation enriches chloride (Cl) and potassium (K) into recovery boiler ash.

Too high Cl and K concentration in recovery boiler ash reduces boiler availability due to increased corrosion and plugging risk.

Ash composition and recovery boiler operation



- Ash chemistry defines ash melting temperatures* (T0, T15, T70)
  - General rule is the higher the Cl and K concentration, the more difficult boiler operation becomes, eventually leading to boiler plugging and to an unplanned shutdown



Source: Reeve, Tran, and Barham (1981), and Backman, Hupa, and Uppstu (1987).

Valmet

Operational risks without real-time ash chemistry data

- Treat more ash than necessary, losing valuable cooking chemicals
- Have an unplanned boiler wash shutdown, losing approx. 3 days of production per shutdown
- Corrode the super heater piping, leading to approx. $6-$35M rebuild much sooner than anticipated or run at low steam temperature and lose electricity

Valmet Recovery Ash Analyzer and Valmet Ash Balance Advisor

Valmet Recovery Ash Analyzer and Ash Balance Advisor

Applications

- Valmet Recovery Ash Analyzer
  - Complete ash chemistry and ash melting temperatures
- Valmet Ash Balance Advisor
  - Real time information of corrosion risk, sticky area and target volume for ash treatment
  - Treat ash only as much as is needed, don't waste valuable sodium (Na)
  - Maximize cleanability and electricity generation

Main features

- Analyze all main ash components as mass percent.
  - Na, K, Cl, CO_3 and SO_4
- On-line ash melting point information as T0, T15, T70
- Patented dry ash sampler
- Reject samplers for ash treatment systems
- First online solution to measure and control recovery boiler ash

Benefits

- Enable true cost optimization between:
  - Boiler production capacity
  - Make-up chemical costs
  - Electricity generation
  - Environmental load

Maximize recovery boiler availability

- Prevent boiler plugging
- Eliminate super heater corrosion risk

- Product launch in April 2021
- Pilot in production use since 2019

Sampling and analyzer location

- The ash sample is taken from the dropping ash flow between the ash conveyors.
- Analyzer is installed close to the mixing tank, maximum sample line (3/4” FEP) length is 160 ft.

Operating principle

Sampler

- Robust stainless-steel sampler based on Valmet's pulp sampling technology.
- Automatic diagnostics for movement and sample flow
- 2 samples per hour

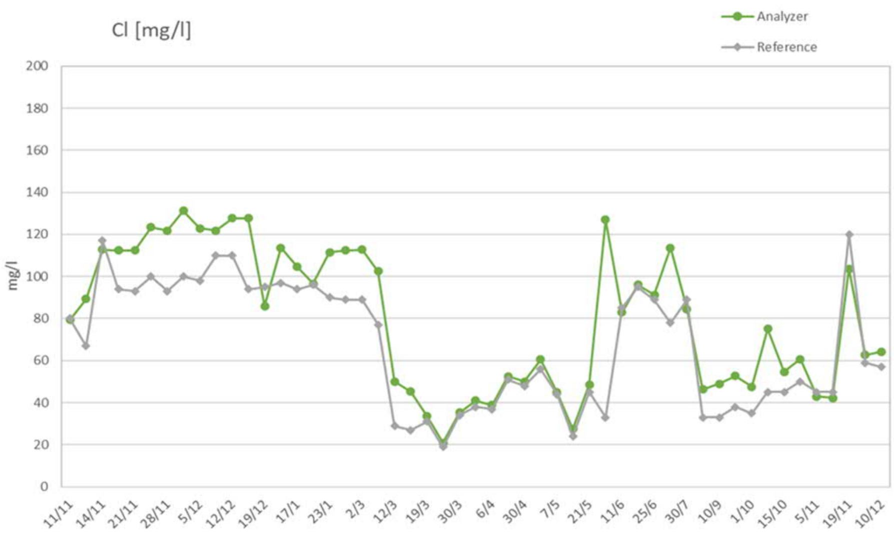
Sample handling

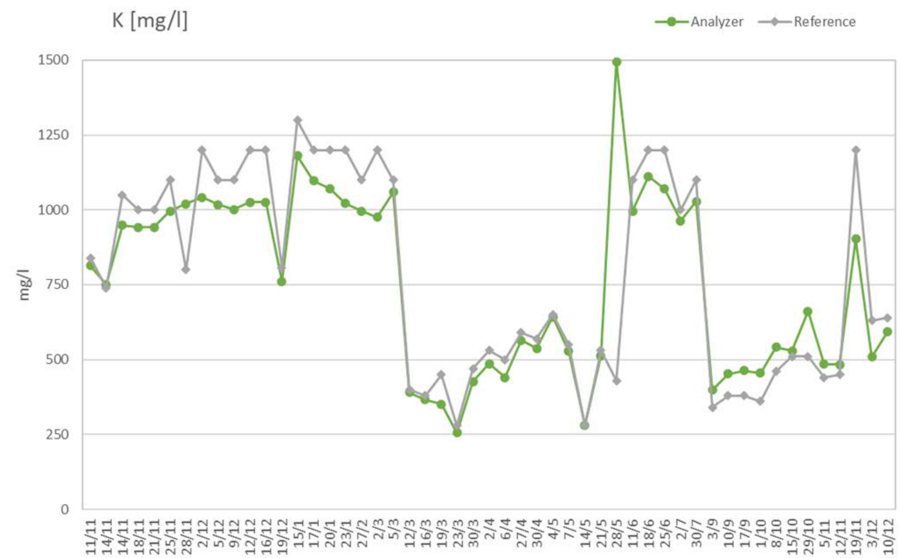
- The ash sample is dissolved in water at the sampler and transferred to the titrator by pressurized air
- Sample is taken from stabilization tank at the titrator
- Automatic flushing and cleaning sequences

Measurements

- Cl: Analyzed by ion selective electrode
- K: Analyzed by ion selective electrode
- CO3: Analyzed by HCl titration (like in Alkali R)
- SO4: Analyzed by BaCl2 titration (like in Alkali R)
- Na: Calculated from mass balance
- Ash melting temperature calculations
  - T0, T15, T70

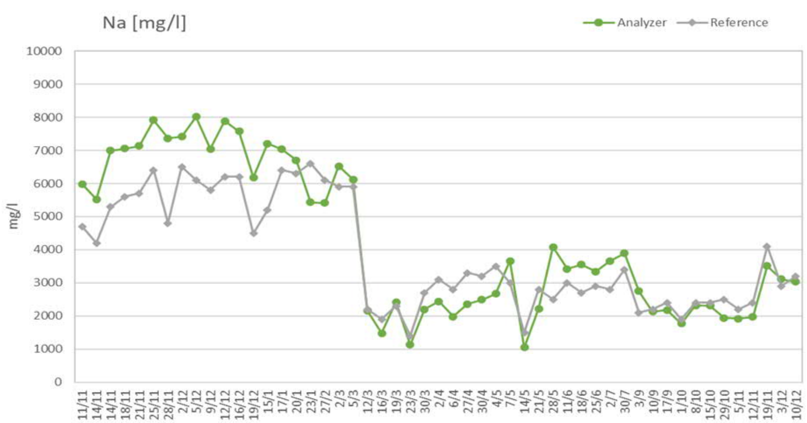
Analyzer Performance





Samples collected and analyzed between 11/2019 and 12/2020

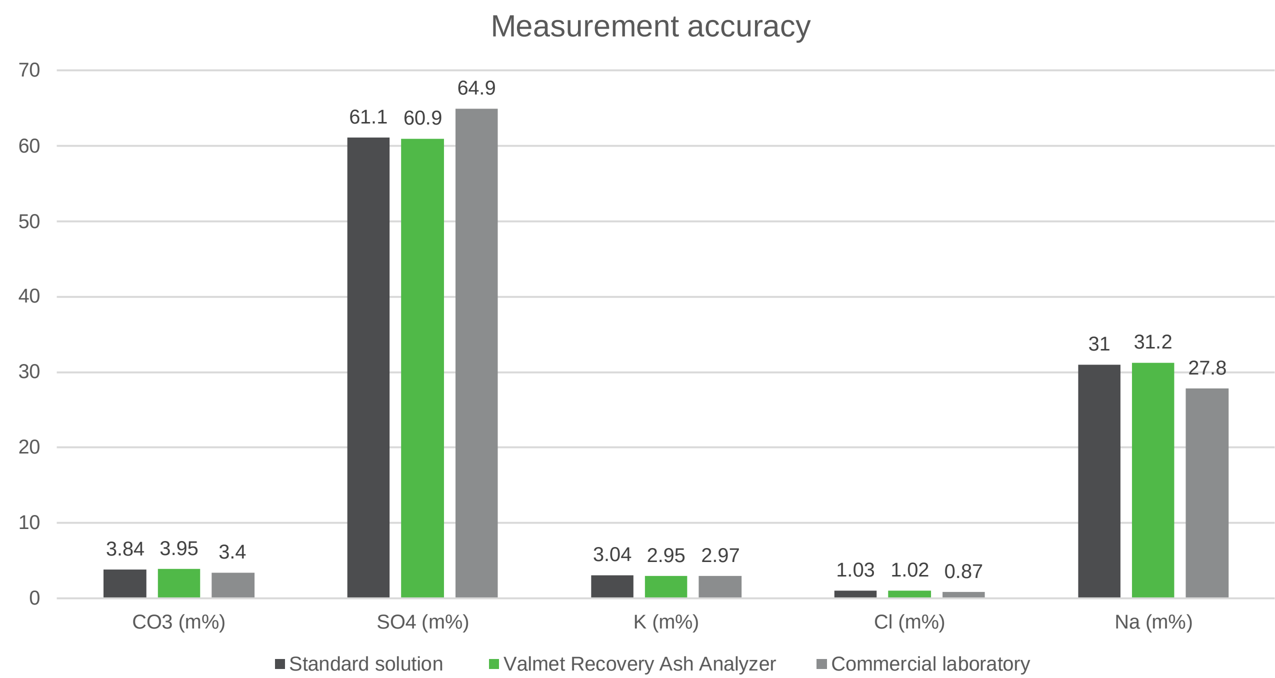
Analyzer performance



Samples collected and analyzed between 11/2019 and 12/2020

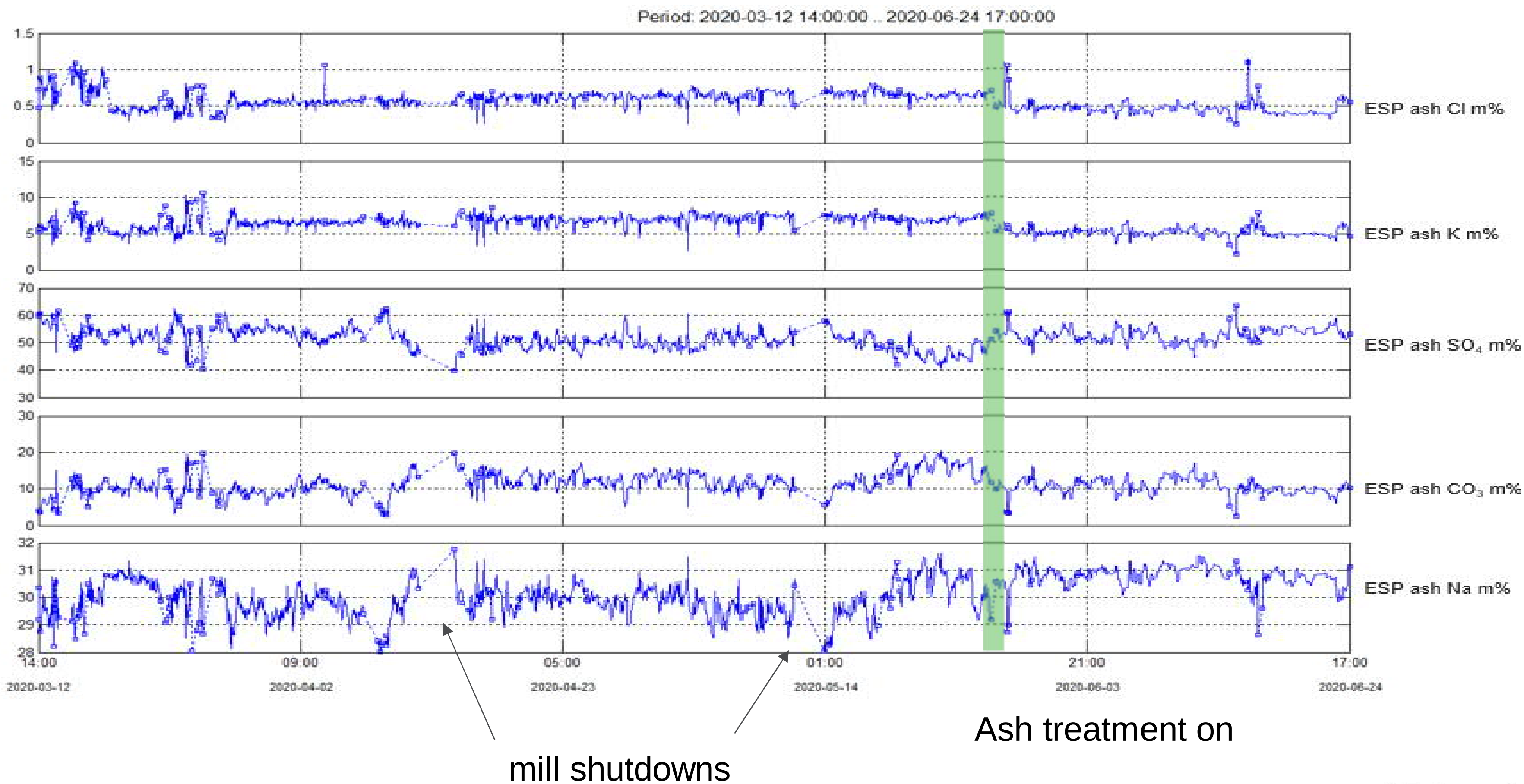
Valmet Recovery Ash Analyzer performance

- Laboratory uncertainty was 10 % for CO_3, SO_4, K, Cl and 15 % for Na
- The standard solution test shows the analyzer performance against the laboratory

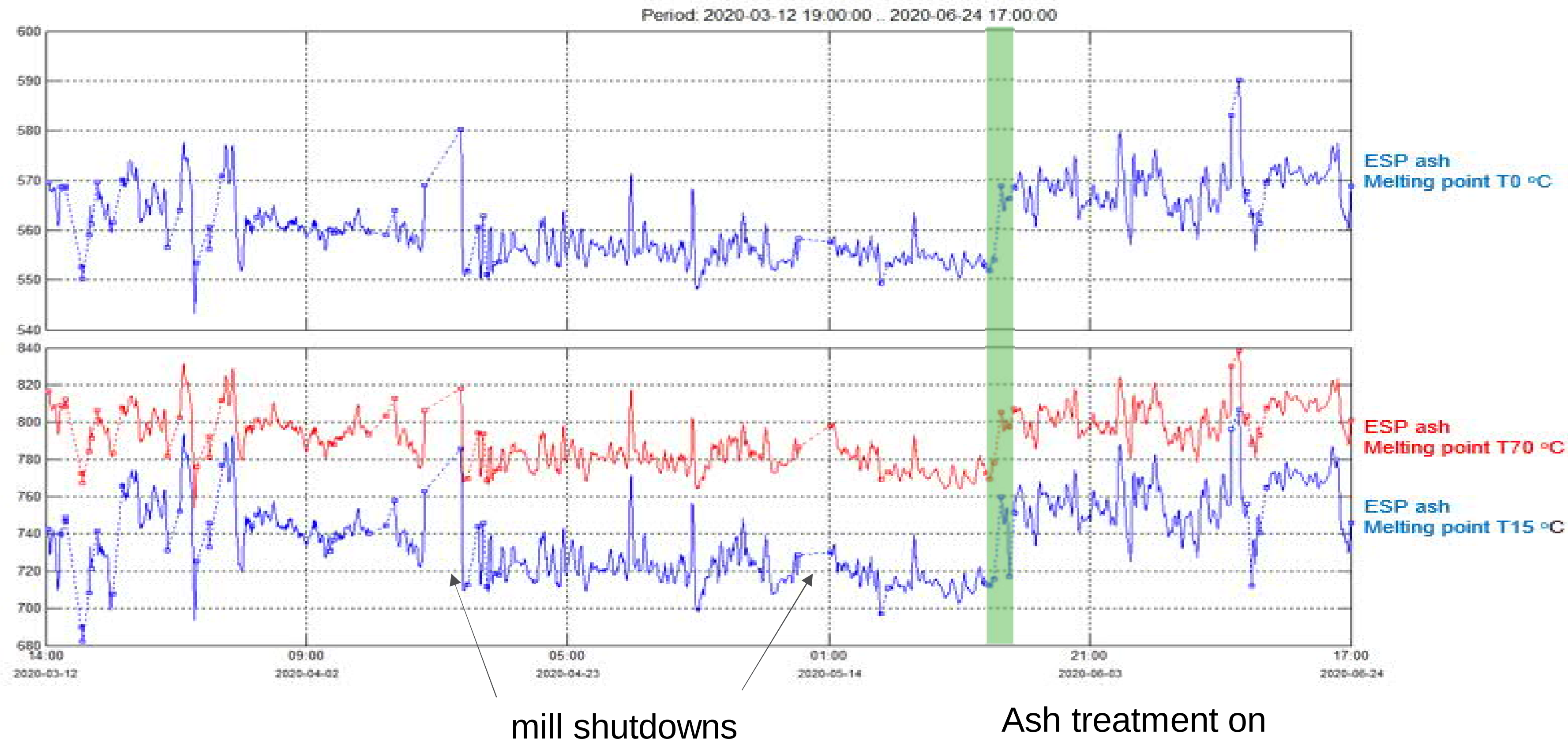


Concentration of standard solution is 100% known and is prepared by weighing analysis chemicals.

Online Ash Chemistry



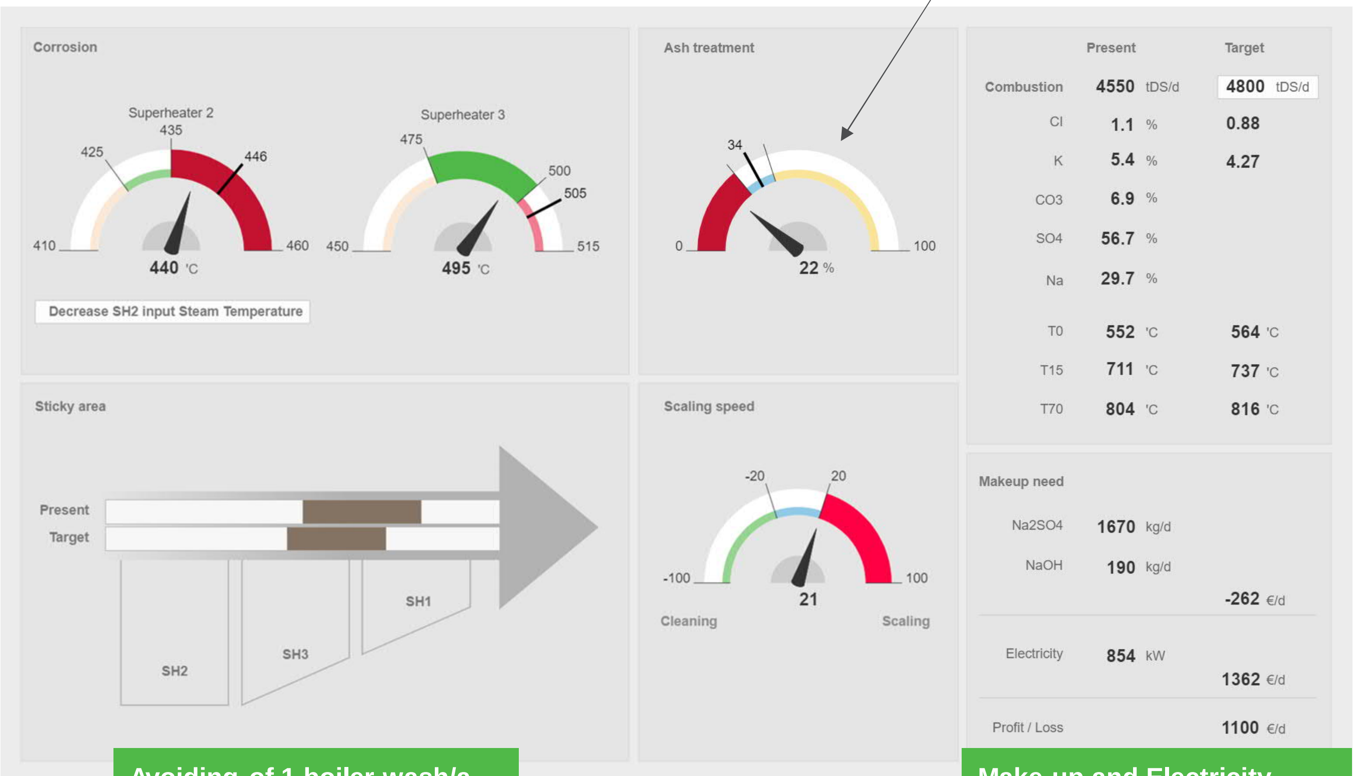
Online Ash Melting Temperatures



Valmet Ash Balance Advisor

Operator's view in Valmet DNA User Interface

Current ash treatment is 22% and advised target is 34%



Avoiding of 1 boiler wash/a 2.0 MEUR/a

Make-up and Electricity revenue balance 400 kEUR/a

Advisor calculates the online status of:

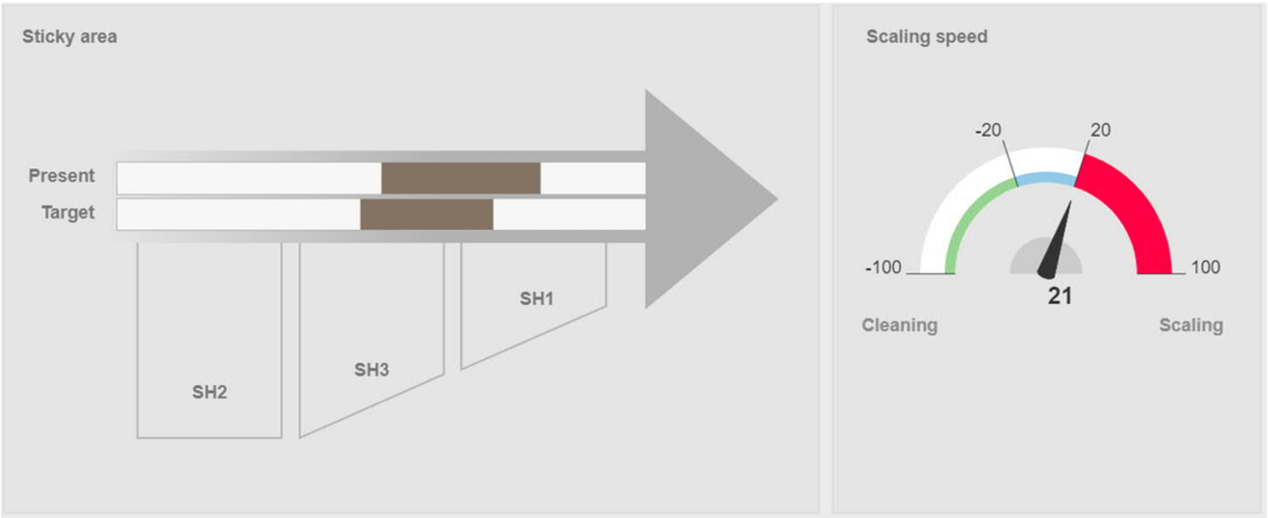
- Corrosion risks
- Steam temperature targets
- Sticky area
- Scaling speed
- Advised change to ash treatment amount

After advised change:

- New ash chemistry
- Operation costs change
- New sticky area
- New maximum steam temperature targets

Valmet Ash Balance Advisor

Recovery Boiler Scaling



Sticky area

- Sticky area indicates critical flue gas temperature area at superheaters where ash is sticky
  - "Present" sticky area indicates where boiler is scaling at current ash chemistry and boiler load
  - "Target" sticky area indicates where sticky area will move to after ash treatment amount has been changed as advised

Scaling Speed

- Indication of superheater area scaling speed
  - Scaling speed is an indication of change in heat transfer from flue gas to steam

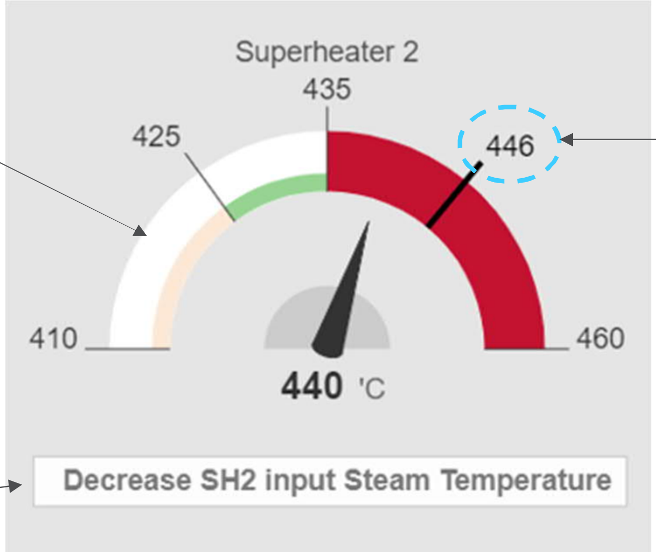
Ash Balance Advisor

Recovery Boiler Corrosion

Superheater 2 corrosion

- Low temperature area indicates outlet steam temperature where SH2 input steam is too wet and may cause tube failures.
- Green temperature range indicates outlet steam temperature where corrosion risk is minimum. This is the target temperature range and 435°C is the maximum in this example.
- High temperature red area indicates temperature range where tube corrosion risk is high.

- Ash Balance Advisor also has “first aid” function
  - This function helps the operator to make corrections to steam temperature targets in order to control corrosion risk while ash chemistry is changing.



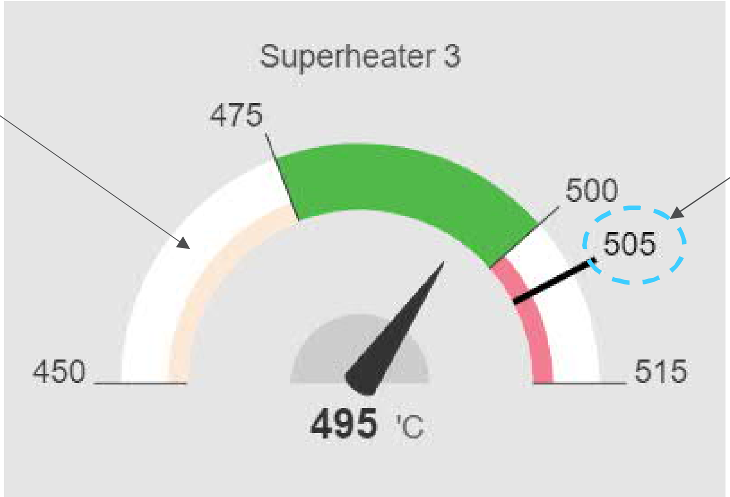
Maximum outlet steam temperature after ash treatment amount has been changed as advised.

Ash Balance Advisor

Recovery Boiler Corrosion

Superheater 3 corrosion

- Low temperature area indicates when outlet steam temperature is too low:
  - Causing erosion at turbine
  - Too moist sootblowing steam can cause tube failures
- Green temperature range indicates outlet steam temperature where corrosion risk is minimum. This is the target temperature range and 500°C the maximum in this example.
- High temperature red area indicate temperature range where corrosion risk is high with present ash chemistry.



Maximum outlet steam temperature after ash treatment amount has been changed as advised.

Conclusions

- Unique solution to measure ash chemistry and advise boiler owner to optimize ash treatment
- Allows optimization of boiler operation to:
  - Maximize boiler run time between outages
  - Minimize operational costs of sodium make-up
  - Maximize electricity generation
  - Protect superheaters

Contact Info

- Valmet would like to specify an analyzer for any mill interested:
  - Contact Travis Conner
    - 757-902-0929
    - travis.conner@valmet.com

High Velocity Thermal Spray & Modified Alloys for Use in BLRBs

MATTHEW MACWATTERS AND KEVIN PHILLIPS

INTEGRATED GLOBAL SERVICES

Corrosion Concerns in BLRBs

- BLRBs lower walls, floors, and studs
- Chlorine (Cl), Potassium (K), and sodium (Na) form low-melting point eutectic salts and smelts
  - Penetrate the protective smelt layer
  - Tube failures directly correlated with smelt penetration and resulting thermal excursions
- **Other concerns:**
  - Formation of black high emissivity deposits
  - High temperature sulfidation
  - Chlorides and SCC (especially during water washing)
  - Galvanic effects with previously installed WO

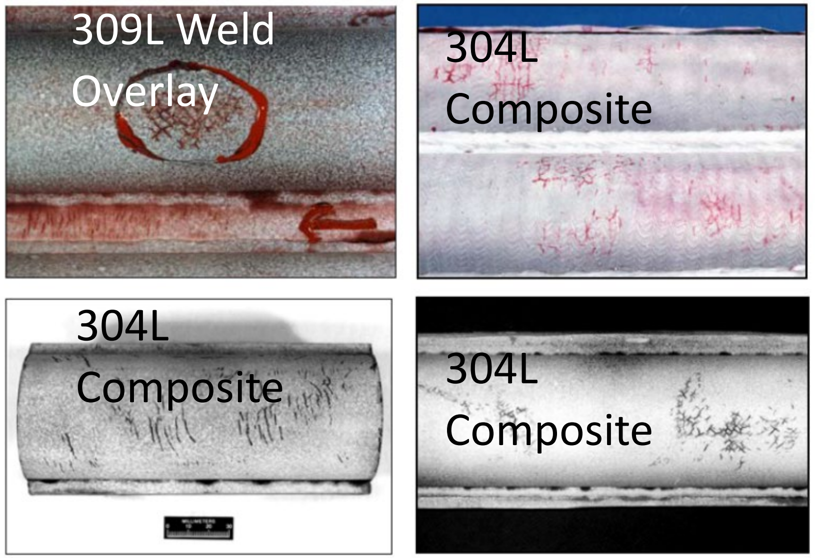


Figure: Dye penetrant testing showing cracking in BLRB floor composite tube sections

Traditional Solution: Weld Overlay

Advantages

- Restoration of vessel thickness and the repair of pits/gouges/cracks
- Forms a corrosion resistant barrier *when installed correctly*

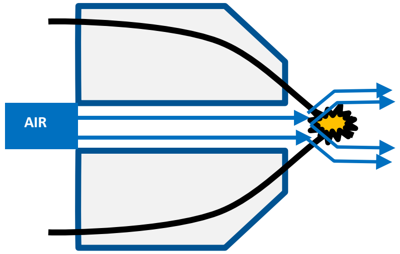
Disadvantages

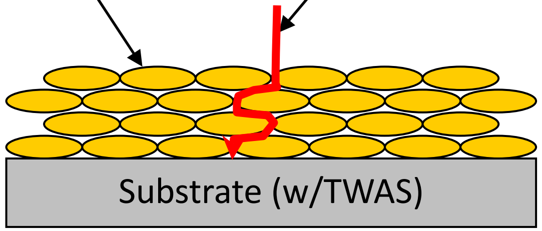
- High cost and long installation time
- Requires extensive surface preparation
- Incorrect installation can lead to latent damage from pinholes and cracking

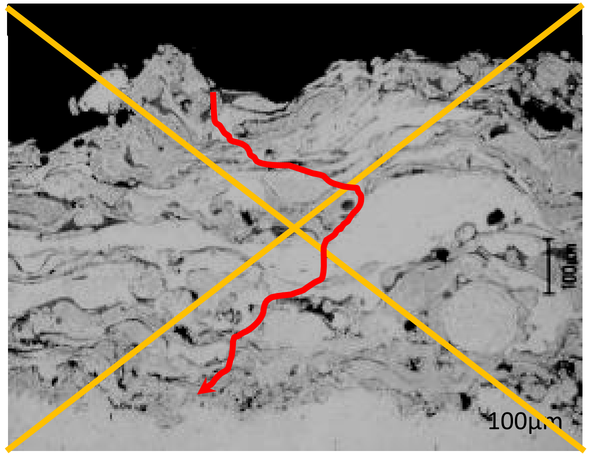
Improved HVTS Technology

Twin Wire Are Spray (TWAS)

- Low Velocity System (sub-sonic)
- High oxide content
- Lower bond strength
- Interconnected oxides & porosity

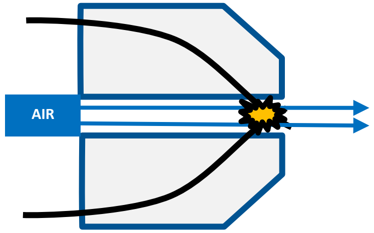


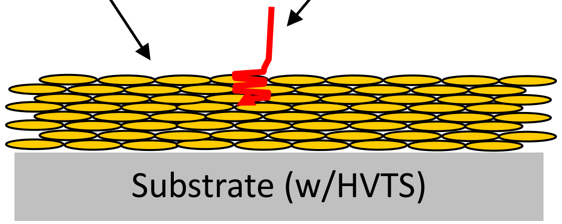


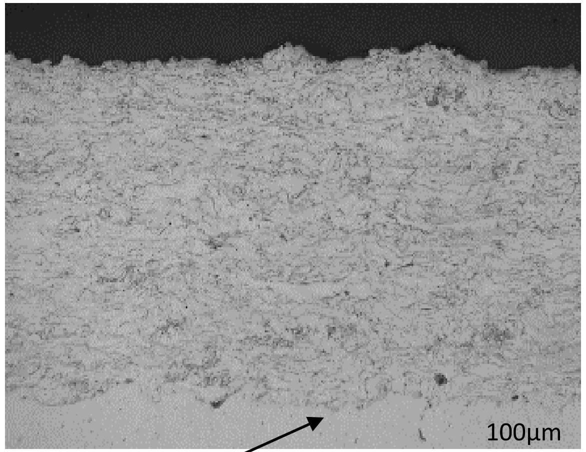


IGS High Velocity Thermal Spray (HVTS)

- Atomized wire in a super-sonic gas stream
- Alloy modification minimizes in-flight oxidation to low levels
- Purposefully engineered to produce a low residual stress cladding



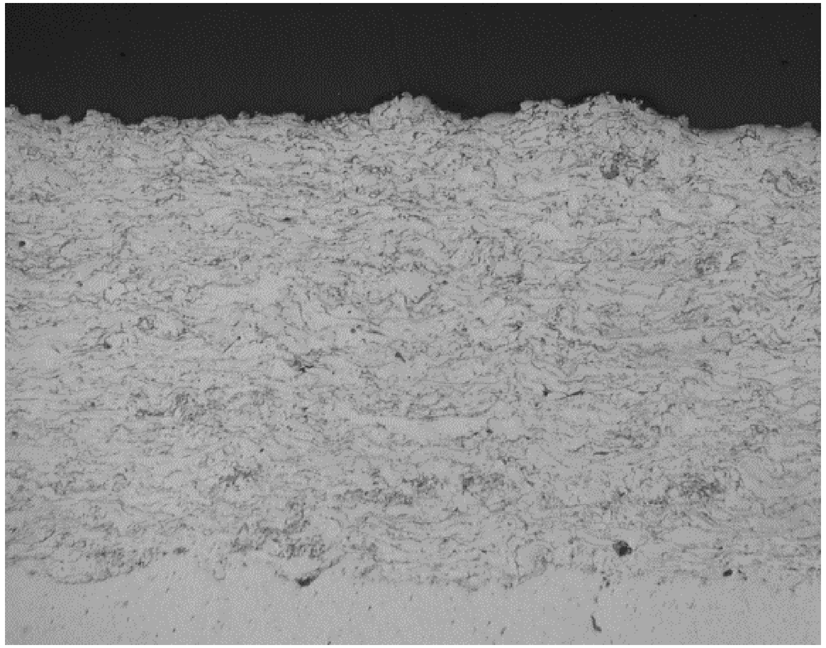




50 MPA bond strength
No heat affected zone (HAZ)

BLRB Specific Alloy – IGS 5450

Engineered, high chromium alloy for use in high temperature corrosion environments



Porosity	<1%
Total Oxides	<2%
Bond Strength	46 Mpa
Melting Point	2372 degrees F

Advantages

- Effective against Erosion and Corrosion
- Less expensive (50-70% less) and faster installation (50-70% faster) than welding / WO
- Gun modifications and lower thickness allow for faster installation than previous thermal arc sprays
- Repairable and easily inspectable

Lab Validation Overview

- **Media:** Corrosive White and Black Liquor obtained from an American paper mill experiencing boiler corrosion. Black Liquor combusted to produce.

- **BLRB Smelt Testing**
  - **Frozen Smelt Testing:** Coupons were covered in a 900°C / 1650°F smelt and placed in an oven at 400°C / 750°F for 2 weeks.
  - **Molten Smelt Testing:** Coupons were submerged in a 900°C / 1650°F bath of molten smelt
    - Represents extended molten smelt exposure (worst case scenario)

Lab Validation – IGS HVTS Alloys

- **Goal:** IGS HVTS, traditional TWAS, and wrought alloy controls for use in corrosive BLRB environments
- Low Velocity Arc Spray was used as a thermal spray control to represent previous generations of technology
- IGS 5450 and 5478 (High Velocity Thermal Spray) were evaluated

Number	Material/Cladding	BLRB Testing		Notes
		Frozen Smelt	Molten Smelt	
1	Carbon Steel	X	X	Control
2	SA387-11-2		X	1.25Cr Tube steel Control
5	45CT - TWAS	X		Traditional NiCr Arc Spray
7	5478	X		FeCrNiV Coating
8	5450	X	X	NiCrX coating tested at 15 mils and 20 mils

Black Liquor / Smelt Analysis

- The plant-sourced BL was analyzed for corrosivity
- Significant levels of chlorides - Can directly attack carbon and stainless steels and form eutectic mixtures
- Contains 4.17% (solids basis) of Thiosulfates ($Na_2S_2O_3$). These are corrosive compounds that can compromise both CS and stainless steels
- Moderate potassium levels – potential eutectic agent in BLRBs

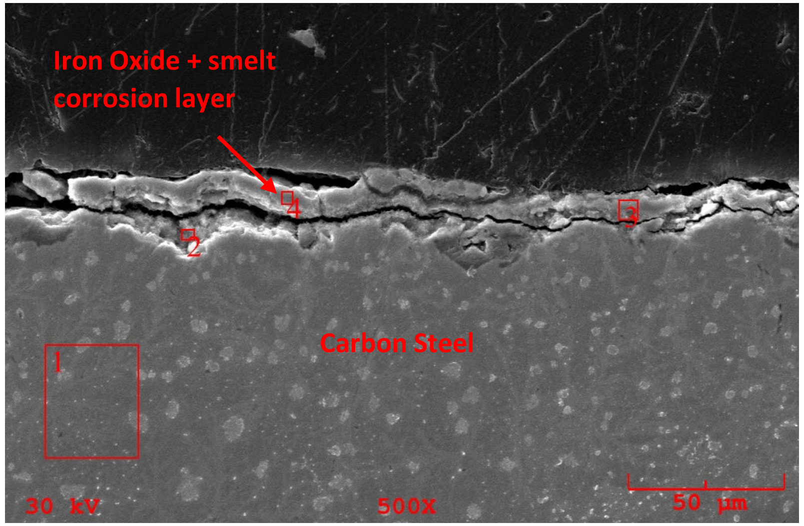
Black Liquor (Plant-Sourced)	
Test	**Results**
Chloride, Cl	0.12%*
Sulfur	4.56%*
Sulfate, as Na_2SO_4	4.09%*
Carbonate, CO_3	3.73%*
Thiosulfate, as $Na_2S_2O_3$	4.17%*
EA/AA/TTA	EA: 4.13%* AA: 6.02%* TTA: 11.6%*
Total Alkali	10.2%*
Metal Scan - Potassium	1.98%*
*Solids-only basis	

Validation Results

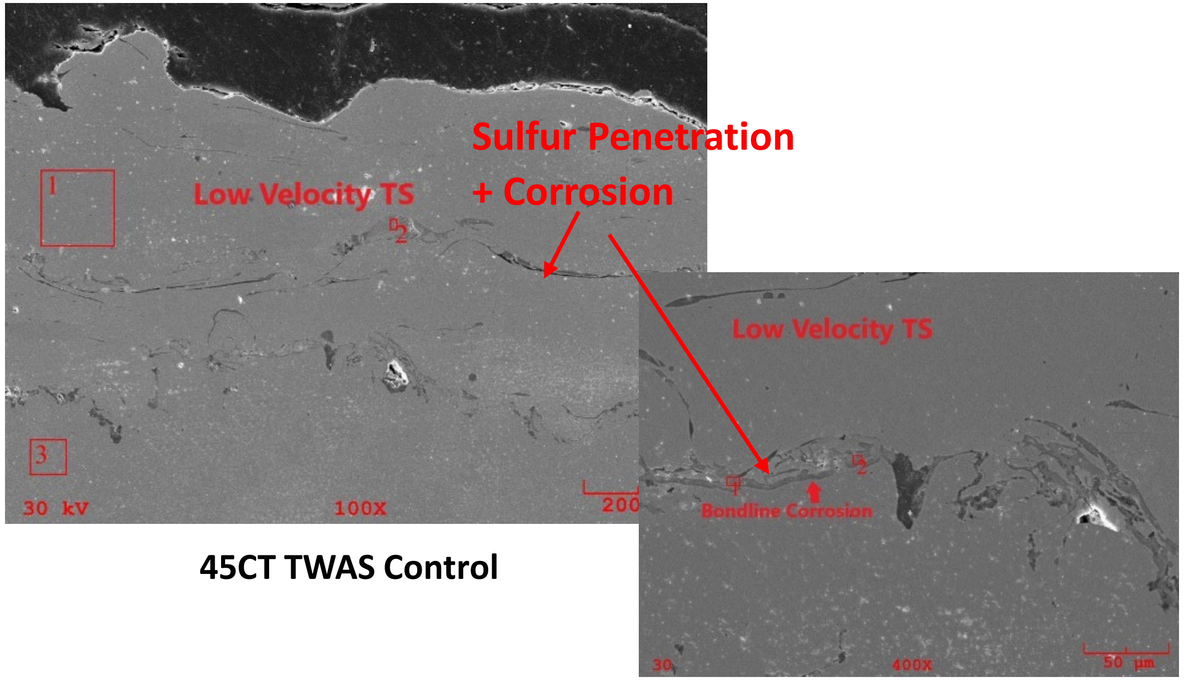
Number	Material/Cladding	BLRB Testing		Notes
		Frozen Smelt	Molten Smelt	
1	**Carbon Steel**	Fail	Fail	Control
2	**SA387-11-2**	Fail	Fail	Control
5	**45CT - TWAS**	Fail		Historical TWAS
7	**5478**	Pass		FeCrNiV
8	**5450**	Pass	Pass	CrNiX (All thickness ranges passed)

Results: Frozen Smelt Test

- Molten smelt was poured on coupons and allowed to freeze. Coupons and frozen smelt were placed in an oven at 400°C for 2 weeks
  - 400°C is above the estimated maximum tube metal temp for high pressure systems
- **Control: Carbon Stee**l (wrought alloy) suffered general corrosion with the formation of an iron oxide and smelt corrosion layer
- **Control: 45CT TWAS** is representative of previous generation of BLRB TWAS systems deployed. Cladding remained intact but allowed sulfur permeation via oxide bands, allowing CS substrate corrosion



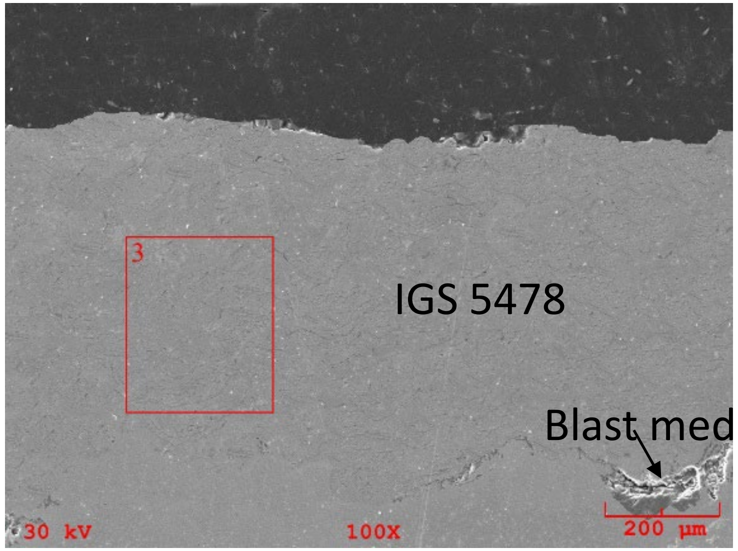
Carbon Steel Control

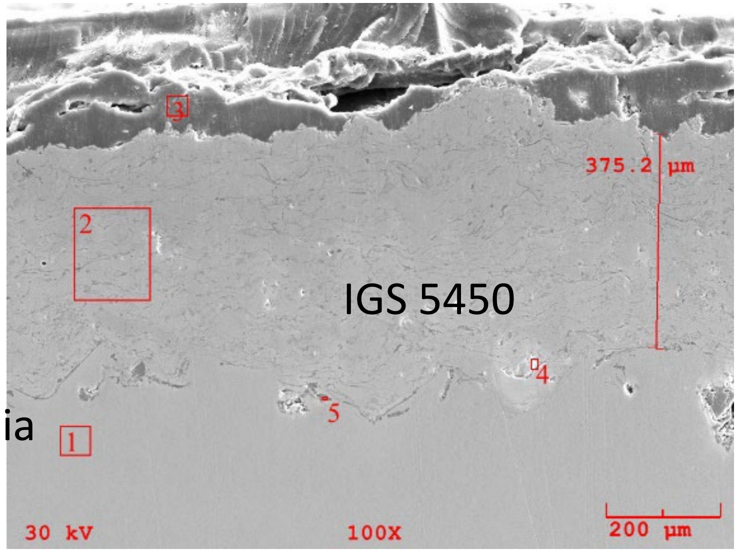


45CT TWAS Control

Results: Frozen Smelt Test

- 5478 (FeCrNiV) and 5450 (NiCrX) HVTS systems were applied as test systems
  - 5450 was evaluated at 15 and 20 mil thicknesses
- Both 5478 and 5450 **passed** corrosion testing: complete substrate protection and no sulfur permeation
- Additional test coupon was coated with 6022 (Blue) anti-slagging ceramic – Easier tube cleaning

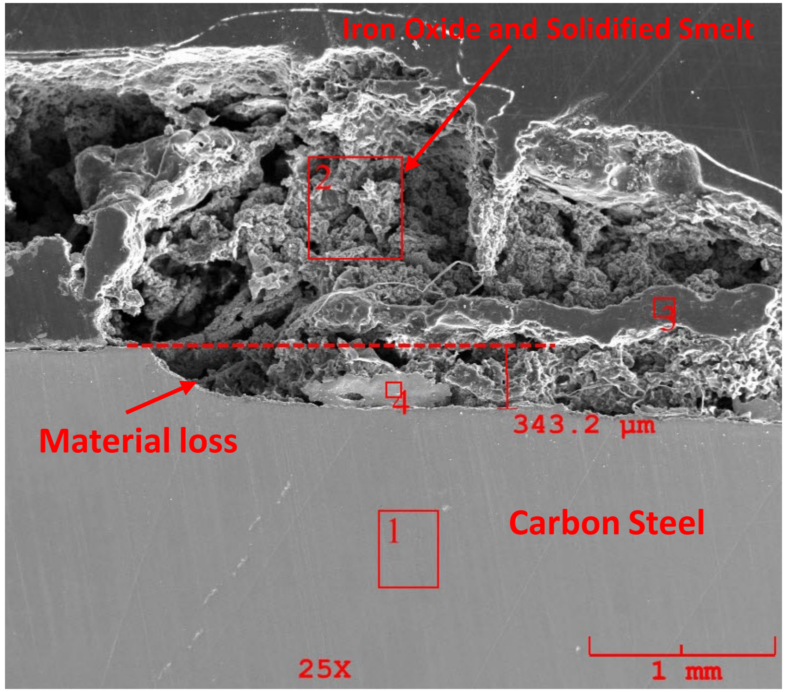




Solid smelt in coupon hole

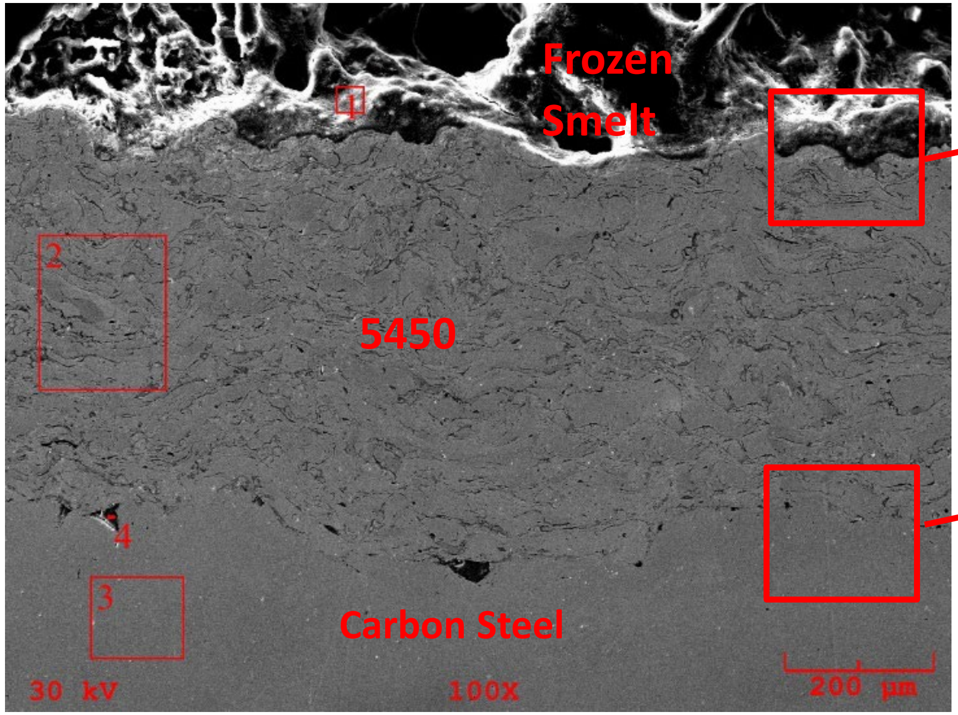
Results: Molten Smelt Test

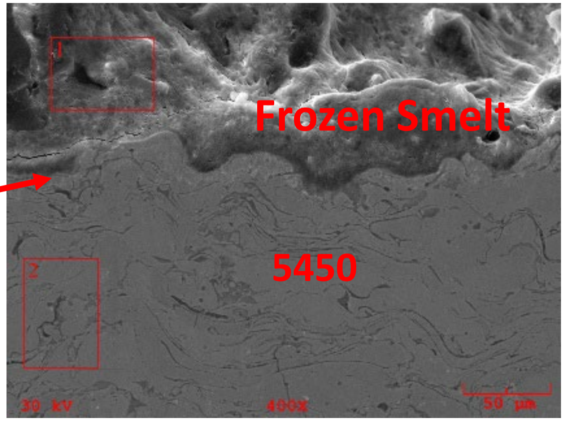
- 1650°F Molten smelt bath - worse case scenario –with extended exposure to molten smelt
- **Control: Carbon steel** lost approximately 343.2 (13.5 mils) microns of thickness to iron oxidation/sulfidation in only 6 hours
- **Control: SA387-11-2 (1.25Cr tube steel)** showed evidence of dealloying and the formation of a chromium sulfide/oxide corrosion scale

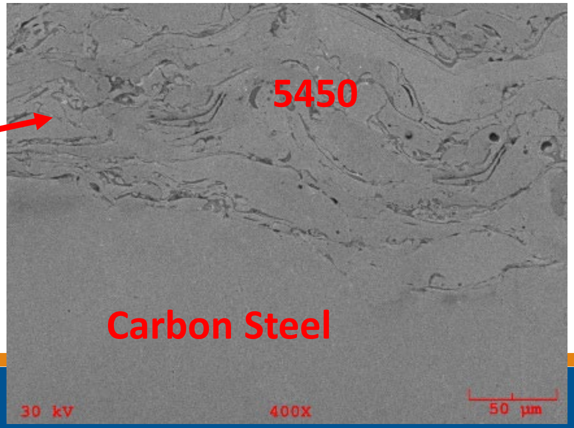


Results: Molten Smelt Test

- **5450** selected based on its performance in frozen slag testing and its high temp resistance
- Passed molten smelt corrosion testing – **Applied at a lower thickness/faster application then traditional TWAS**
- No evidence of corrosive media penetration or CS substrate attack. No signs of HVTS degradation at the HVTS/smelt interface







HVTS Case Study

Northeastern US Recovery Boiler - 2011

- Band of corrosion just above the lower boiler composite tubes – 8 to 14 mils of wastage per year
- Intensive scaffolding and pad welding to repair thickness every 18 months
- **Results:** HVTS is still in good condition 10 years later
  - Pad welding is no longer required, shortening turn-around times, and HVTS cladded area has been expanded

Other Pulp and Paper Validation

- **Alloys have been validated in additional pulp and paper environments**
- **Digester/Evap Autoclave Testing**
  - **2-week** test runs in both White and Black Liquor were conducted
  - Simulated a digester at the beginning and end of a cook cycle
  - All IGS alloys passed testing – Control and TWAS suffered corrosion

Conclusions

Number	Material/Cladding	BLRB Testing		Notes
		Frozen Smelt	Molten Smelt	
1	**Carbon Steel**	Fail	Fail	Control
2	**SA387-11-2**	Fail	Fail	Control
5	**45CT - TWAS**	Fail		Historical TWAS
7	**5478**	Pass		FeCrNiV
8	**5450**	Pass	Pass	CrNiX (All thickness ranges passed)

Recommendations:

- 5450 HVTS is recommended for use in BLRB, Digestor, and Evaporator vessels.
- TWAS applied coatings are no longer recommended for long term service conditions.

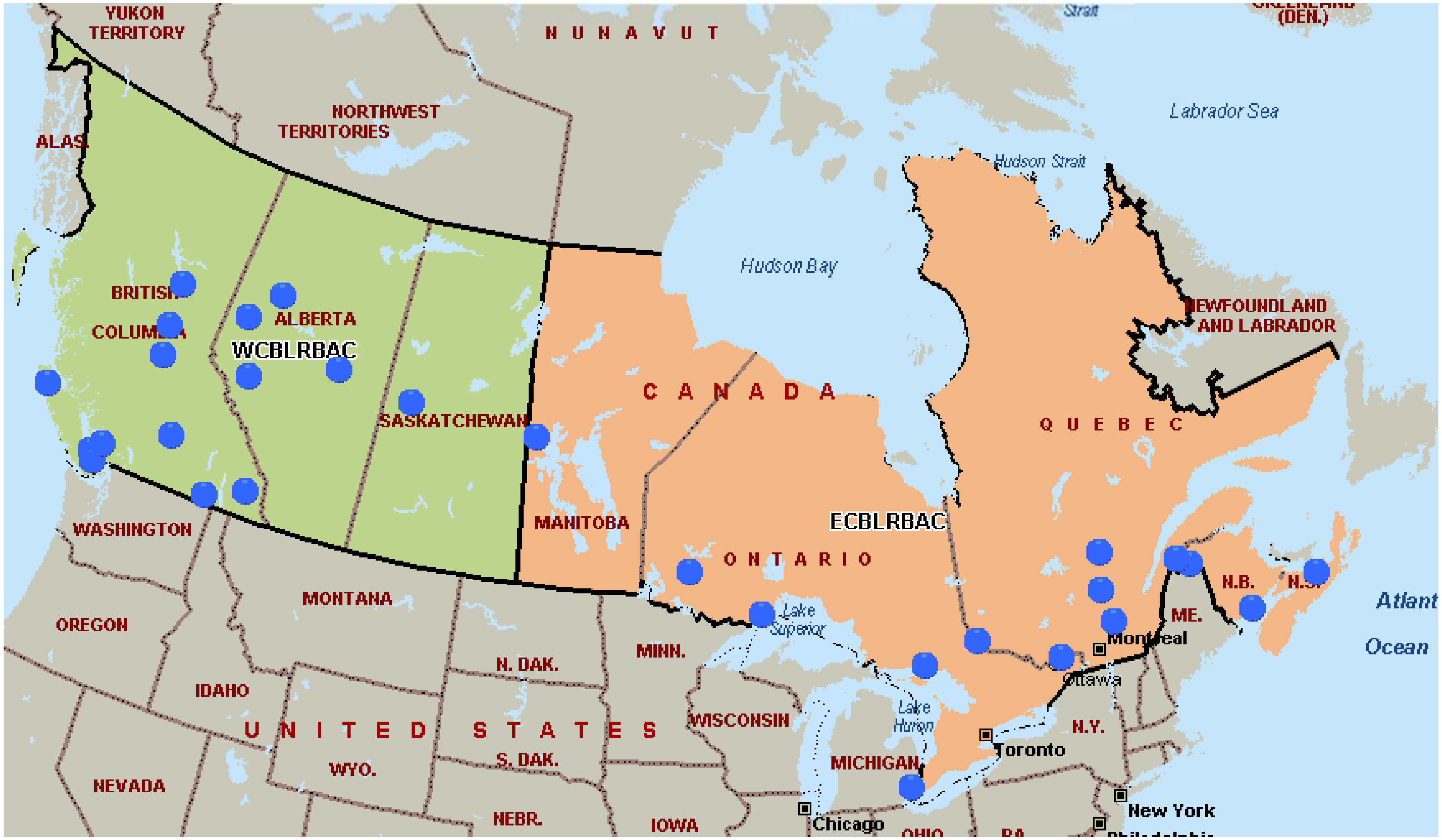
Contact: Kevin Phillips (kevin.phillips@integratedglobal.com)

Canadian BLRBAC

Report on 2021 Activities and 2022 Plans

Dean Clay for 2022 AF&PA Recovery Boiler Annual Conference

Western and Eastern Canada BLRBAC



ECBLRBAC (Eastern Canada)

- Feb 11, 2021, Virtual, part of PAPTAC's PaperWeek

10:00 - 11:30

- Recovery Boiler Safety
- Session Chair: Aaron Ferris, Irving Pulp & Paper
- 10:00 "Around the Table" Part 1 - Roundtable discussion on Incident Reports,
- Mill Safety, Near Misses, Energy Savings, Operations, and Training"
- 10:30 "Around the Table" Part 2 - Roundtable discussion on Incident Reports,
- Mill Safety, Near Misses, Energy Savings, Operations, and Training"
- 11:00 "Around the Table" Part 3 - Supplier Updates presentations"

ECBLRBAC (Eastern Canada)

11:30 - 12:00, Feb 11, 2021

- Networking and Tradeshow
- Recovery Boiler Technology
- Session Chair: Aaron Ferris, Irving Pulp & Paper

- 12:00 "Technical Merits of Reclaiming Green Liquor Dregs to the Chemical
- Recovery Cycle in Kraft Mills", Moise Dion, Mercer Peace River
- 12:30 "Environmental Footprint Benefits from Optimized Boiler Treatment
- Case Study", Grégoire Poirier-Richer, SUEZ - Water Technologies & Solutions
- 13:00 "Improved Recovery Boiler Operation - Role of Research" Nikolai
- DeMartini, University of Toronto

ECBLRBAC (Eastern Canada)

13:30 - 14:00, Feb 11, 2021

- Networking and Tradeshow
- Recovery Boiler Technology
- Session Chair: Aaron Ferris, Irving Pulp & Paper

- 14:00 "Fire Side Additives", Jijo George, Polyrheo
- 14:30 "Review of ESP Subcommittee Learnings from Reported
- Incidents", John Andrews, ESP Subcommittee
- 15:00 Summary Discussion and Wrap-Up
-
- 15:30 - 17:00
- Networking and Tradeshow

ECBLRBAC (Eastern Canada)

- Plans for 2022 are not finalized yet

WCBLRBAC (Western Canada)

- WCBLRBAC only did a limited online meeting with the Steam Chiefs in September 2021
-
- We had an online meeting with just the steam chiefs, but it was pretty informal and just a check in to see how people were doing and get updates from the mills. Was good to chat with the mills again. We are continually monitoring the situation around covid and still hope to have an in person meeting this spring but time will tell.

SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Finnish Recovery Boiler Committee Report

February 2, 2022

Antti Tikkanen, Emma Kärkkäinen & Sakari Vuorinen

Content

Overview of FRBC

Overview of recovery boilers in Finland

Incident statistics 2001 - 2021

Committee activities

Overview of FRBC

Introduction

- The Finnish Recovery Boiler Committee (FRBC) has promoted **safe**, **efficient** and **environmentally friendly** operation of recovery boilers and closely related processes since 1964.

- The Committee…
  - collects information about incidents involving recovery boilers and provides details of these to its members
  - publishes guidelines, recommends practices, and arranges conferences and meetings
  - conducts and supports research projects related to safe operation and improved economy of recovery boilers

FRBC Members

- The members of the Committee include pulp mills, recovery boiler manufacturers, a number of insurance, engineering and inspection companies and research organisations in Finland.
- Total 30 members, including 15 pulp mills
  - 25 voting members, 5 universities
- A yearly member fee is collected from the Committee members

Organisation

Annual Meeting
25 voting members

Board
Chairman*: Ville Korhonen, Stora Enso
10 members + secretary

*Chairman term is 2 years

Secretaries
Antti Tikkanen*
Sakari Vuorinen
Emma Kärkkäinen
Päivi Lampinen

*Until Feb 2022

Durability sub-committee
12 members + secretary

Environmental sub-committee
9 members + secretary

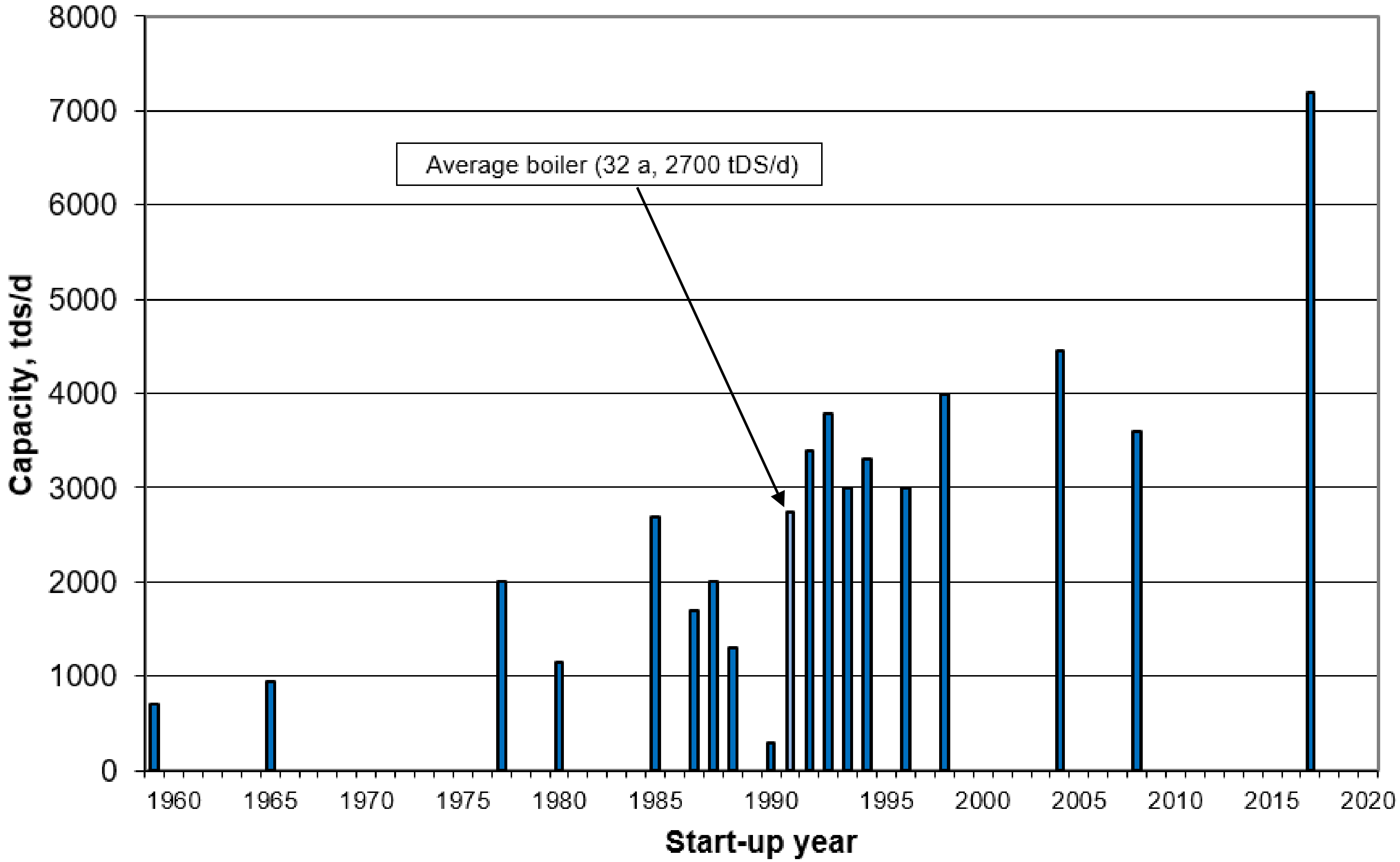
Automation sub-committee
8 members + secretary

Black Liquor sub-committee
11 members + secretary

Program sub-committee
5 members + secretary

Overview of Recovery Boilers in Finland

Finnish Recovery Boilers

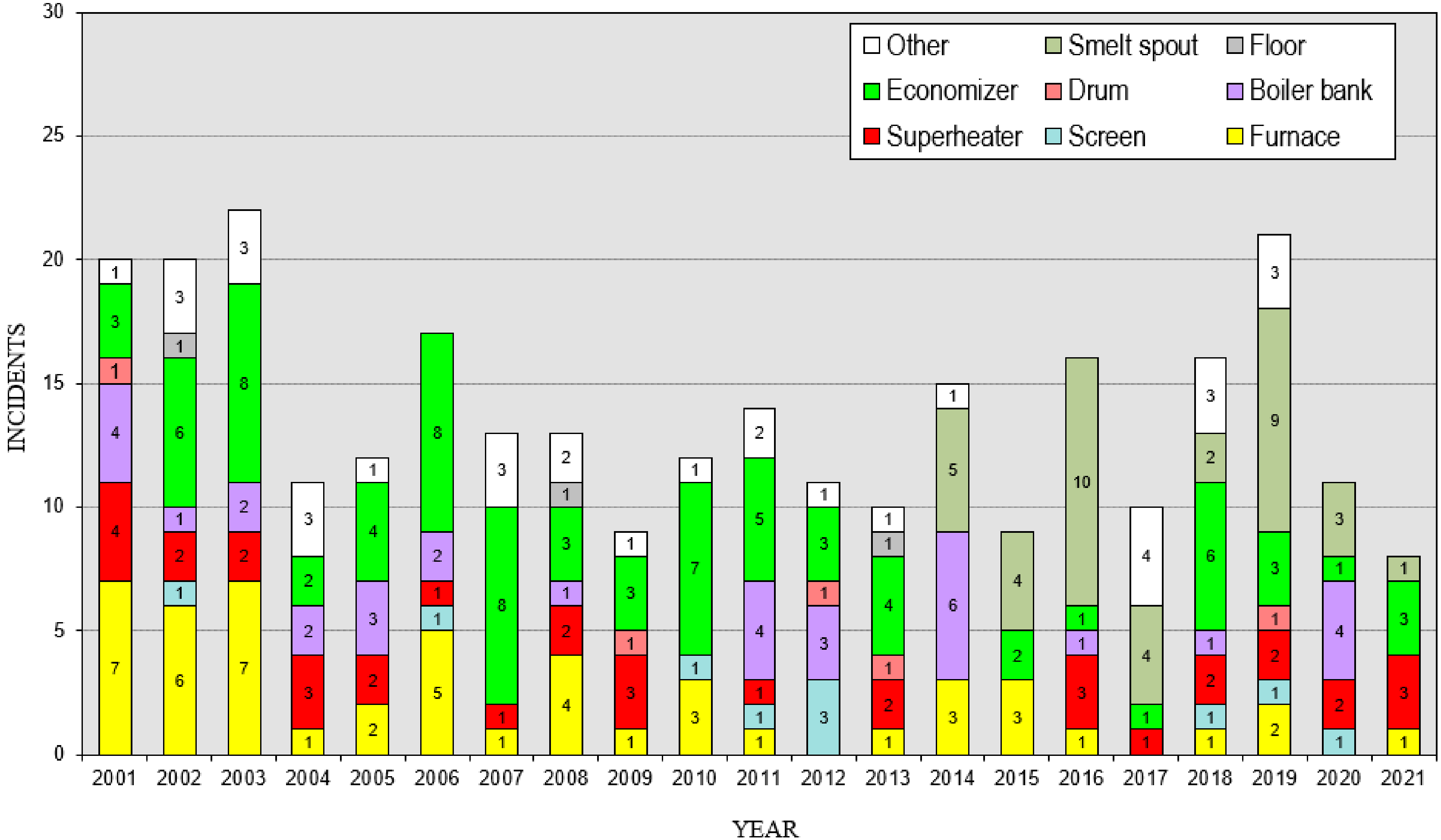


Finnish Recovery Boilers

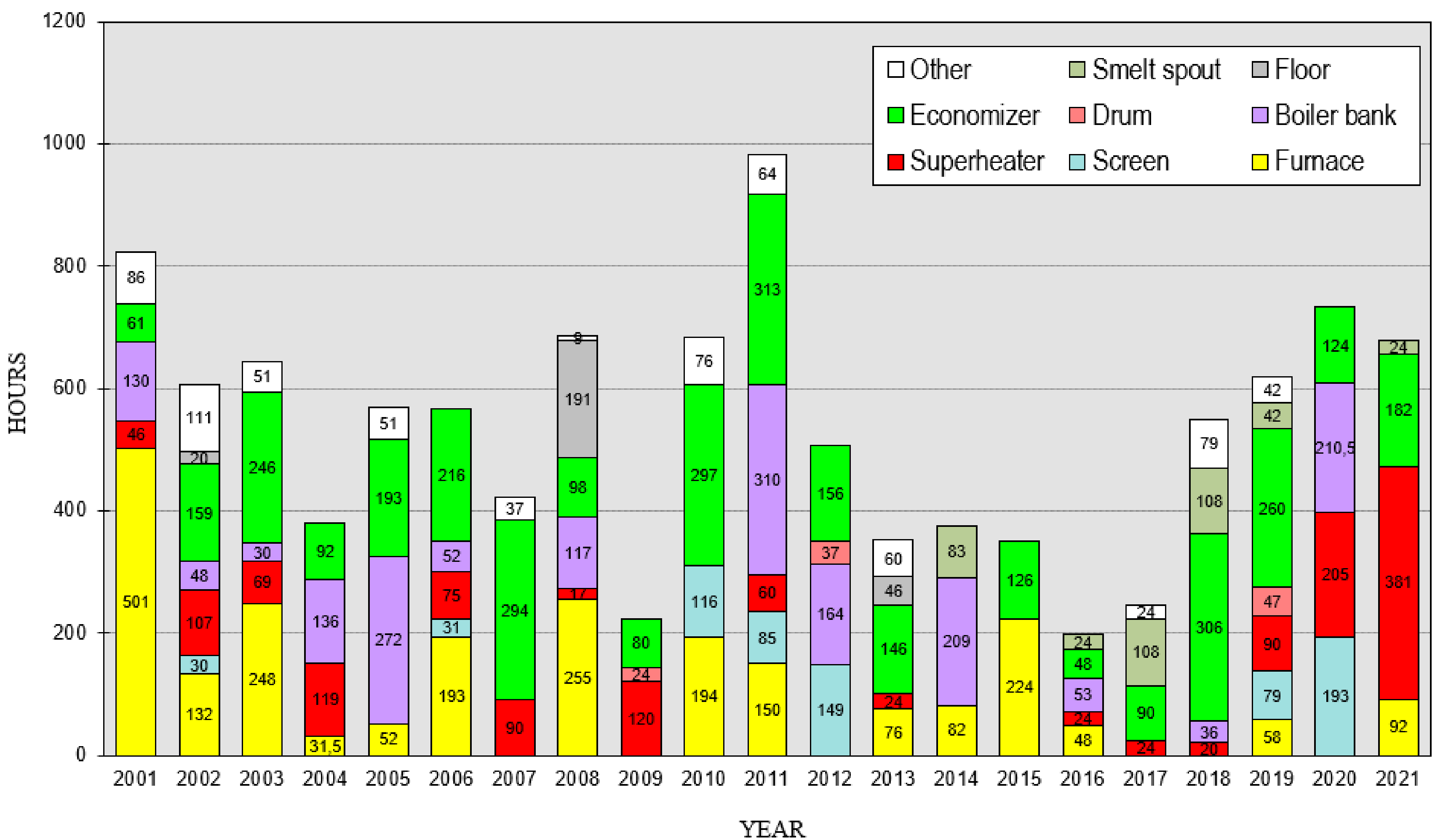
- No. of recovery boilers 18
  - Oldest started up in 1959, CE boiler (700 tDS/d) in Kotka Mills
  - Most recent boiler start-up in 2017 in Metsä Fibre Äänekoski mill, it is also the largest recovery boiler (7200 tDS/d, Valmet boiler)
  - Smallest in Stora Enso Heinola mill, Tampella boiler (300 tDS/d)
- Number of mills 15
  - Two mills operate more than one RB
- Average boiler age 32 yrs (1990)
- Average boiler capacity 2700 tDS/d
- Combined capacity 51 275 tDS/d

Recovery Boiler Incidents Statistics 2001 - 2021

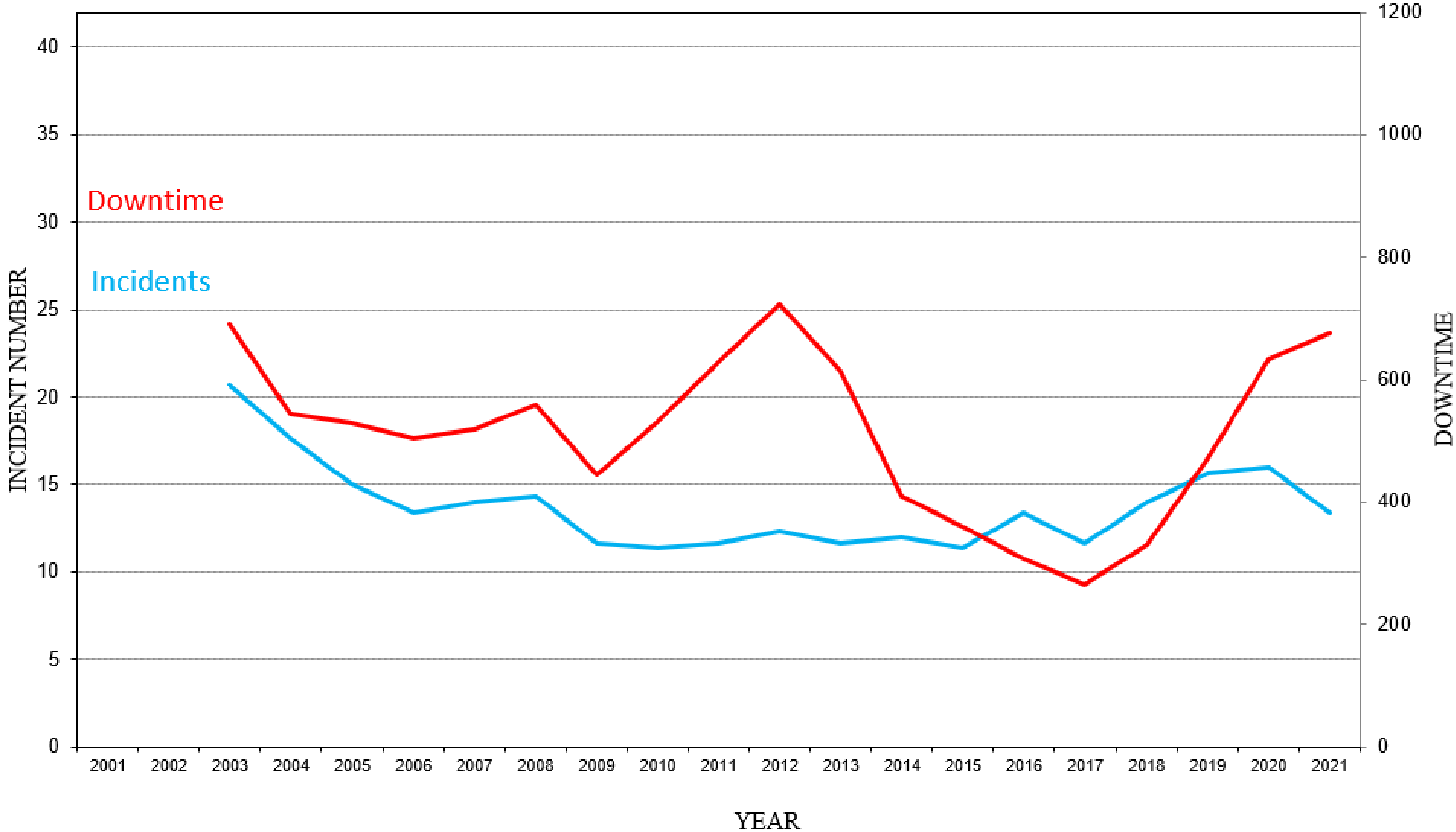
INCIDENTS 2001-2021



DOWNTIME IN FINLAND 2001-2021



INCIDENTS and DOWNTIME trends
3-year running average



Committee Activities

Activities

Recovery boiler day 2019 in Helsinki

- Annual events 2021:
  - "Chief Engineer Day" seminar was cancelled
  - Annual Meeting was arranged on April 21st, 2021 (online event)
  - "Operators' Day" seminar was cancelled
  - "Recovery Boiler Day" seminar was organized on November 4th, 2021 in Helsinki

Activities

- Annual events planned for 2022:
  - “Chief Engineer Day” seminar, April 6th-7th
  - Annual Meeting in April
  - “Recovery Boiler Day” seminar in November 2022
  - “Operators’ Day“ seminar, Fall 2022

Finished projects in 2021

- Lime kiln alternative fuels and emissions
- Update of recommended procedure for incineration of NCGs
- Alkali chloride induced superheater corrosion
- Ion exchange in boiler water production
- Superheater deposit formation and aging
- Update of RB safety interlocking recommendations

Projects in 2022

- Superheater area temperature variation in boilers of different size
- Update for RB material recommendations
- IT security related to recovery boiler automation systems
- Ceramic furnace materials
- Recommendation for boiler operator PPE (update)

Project highlight

- Lime kiln alternative fuels and emissions
  - Questionnaire sent to Finnish pulp mills
  - 7 mills participated
  - Emissions reported for lignin, tall oil pitch, wood powder and gasified bark
  - Effects on NPEs studied
  - Indirect emissions discussed

Project highlight

- Update of recommended procedure for incineration of NCGs
  - Revision C (previous revision in 2013, original in 2003)
  - Main changes:
    - Collection of NCGs
    - Automated incineration in different incineration points (e.g. RB, H2SO4 preparation, NCG boiler, flare, power boiler)
    - Identification of process risks)
    - Introduction of EU BAT in NCG handling

More information in English coming soon:
www.soodakattilayhdistys.fi

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Emma Kärkkäinen
emma.karkkainen@afry.com

BLRBAC

Report on 2021 Activities and 2022 Plans

Dean Clay for 2022 AF&PA Recovery Boiler Annual Conference

BLRBAC Basics

Black Liquor Recovery Boiler Advisory Committee

- Objective - promote improved safety of recovery boilers through the interchange of knowledge, experience and data.
- Meetings in April and October in Atlanta
  - **next meeting April 4 – 6, 2022**
    - **Not yet determined if it will be in-person, or virtual**
  - Be sure to check the dates of future meetings
  - Scheduled October 2 – 5, 2022 Meeting
- Members are from recovery boiler: operating, manufacturing and insuring companies.
  - Only Members can vote
  - Also have associate members with direct interest
- Note – BLRBAC is incorporated.

BLRBAC Internet Site

- blrbac.net (old site blrbac.org is no longer active)
- Guidelines and questionnaires
  - Latest versions
  - Draft revisions for review
    - Interested persons are urged to review and provide comments, before the revisions are voted on for approval.
- Articles of Association & Operating Procedures
- Meeting registration forms and information
- Meeting minutes, current and past (to 2001)
- RBs in Service, U.S., Canada
  - Help keep the lists up to date, name changes, closures

Registration

- Barbara Holich, has retired, no longer involved with BLRBAC
- MetroConnections is now handling BLRBAC meeting registrations. A link is provided on blrbac.net, credit cards are accepted.
- Discussed increase to $300 Advance; $350 @ Door
  - Proposed cost was increased after the Spring 2021 meeting, needed to cover rising expenses
- Sonesta (was Crowne Plaza) Atlanta Airport North
  - Free shuttle to and from airport/MARTA
- Spring 2021, Virtual 167 registered
- Fall 2021, Virtual, 95

Recent Meetings

- Spring 2020 Canceled
- Fall 2020, Virtual, 265 registered, including 97 off shore
  - Proving $0 fee will attract many
  - Covered all ESP Incident Reports for 2020
- Spring 2021, Virtual, 167 registered
- Fall 2021, Virtual, 95

BLRBAC Internet Site, Current Posted Guidelines (2018 last revs.)

Recommended Good Practice For Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers
(Dated: October 2018)
Safe Firing of Black Liquor in Black Liquor Recovery Boilers
(Dated: April 2016)
Materials & Welding Guidelines
(Dated: April 2013)
Safe Firing of Auxiliary Fuel in Black Liquor Recovery Boilers
(Dated: February 2012)
Fire Protection in Direct Contact Evaporators and Associated Equipment
(Dated: February 2016)
Personnel Safety & Training
(Dated: April 2018)
Application of Rotork Actuators on Black Liquor Recovery Boilers
(Dated: October 2005)
Boiler Water Management Guidelines for Black Liquor Recovery Boiler
(Dated: April 2016)
Instrumentation Checklist and Classification Guide for Instruments and Control Systems
Used in the Operation of Black 9Liquor Recovery Boilers (Dated: April 2014)
Thermal Oxidation of Waste Streams in Black Liquor Recovery Boilers
(Dated: April 2017)

BLRBAC Updated Guideline Example

<u>Recommended Good Practice For Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers</u> (Dated: October 2018)

CHANGES are listed at the end of the document

October 2018

Recommended Emergency Shutdown Procedure (ESP) & Procedure for Testing ESP System for Black Liquor Recovery Boilers was combined into a single document with Guidelines for Post-ESP Procedures for Black Liquor Recovery Boilers, titled Recommended Good Practice for Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers

- Chapter 2 – Clarified that all motorized valves in ESP system should be wired to bypass any local selector switches and any change be functionally tested
- Chapter 2 – The torque limits, and any other device designed to protect the motor or valve, should not be included in the motor control open circuit for the rapid drain valves
- Chapter 2 – Valves used for final pressure reduction that may be used for other functions must function in the event of an ESP
- Chapter 3 – A DCS page showing ESP functions and their status is suggested
- Chapter 3 – A leak located below the ESP rapid drain valve level (8’) is added to conditions for consideration of floor inspection after and ESP

BLRBAC Internet Site, Documents for Review and Comments

- Recommended Good Practice For Design Operation and Testing of the Emergency Shutdown System For Black Liquor Recovery Boilers - April 2019 Draft
- Safe Firing of Black Liquor in Black Liquor Recovery Boilers - April 2019 Draft
- Boiler Water Management Guidelines for Black Liquor Recovery Boilers - Section 31. 5.1 Revisions - 2018 Draft
- Copper Induced Cracking in Boiler Tubes – May 2019 Draft
- Fire-Protection-for-DCE-2021-Draft

BLRBAC Executive Committee
Revised after Spring 2021 Meeting

- **Chairman – David von Oepen, WestRock**
- **Vice Chairman – Frank Navojosky, International Paper**
- **Operator Rep. – Open**
- **Insurance Rep. – Jimmy Onstead, FM Global**
- **Boiler Mfg. Rep. – John Phillips, Andritz**
- **Treasurer – Len Olavessen, LENRO, Inc.**
  - **to retire ??, looking for replacement**
- **Secretary – Everett Hume, FM Global**

BLRBAC Subcommittees (10)

- ESP (Emergency Shutdown Procedure), John Andrews, Chairman
- Safe Firing of Black Liquor, Vernon Blackard, Chairman
- Safe Firing of Auxiliary Fuel, Bruce Knowlen, Chairman
- Personnel Safety, John Fredrickson, Chairman
- Instrumentation, Dave Avery, Chairman
- Waste Streams, Paul Seefeld, Chairman
- Fire Protection in Direct Contact Evaporator, Stephen Cox, Chairman
- Materials & Welding, Mike Blair, Chairman
- Water Treatment, Tom Przybylski, Chairman
- Publicity & News, Matt Paine, Chairman

- Review the posted BLRBAC Minutes to see what the subcommittees are working on

How to Participate in a BLRBAC Meeting

- Check the schedule for Open Subcommittee meetings, on Monday
  - Closed meeting are for subcommittee members only, to allow focus on assigned tasks.
  - Open meetings can be found in both the morning and afternoon.
- Attend an open meeting that interests you
  - Review the posted subcommittee agenda (available in the meeting schedule in the advance registration materials), and minutes from the previous meeting on the website
  - Usually they will also accept visitor questions on their guidelines, or related topics. You can always send questions ahead of time to the subcommittee Chairman.

Participating in BLRBAC – cont'd

Example from the Spring 2020 Meeting Registration Materials, Monday Meeting Schedule

- **8:00 am – Noon, Personnel Safety Subcommittee - (OPEN)**
- Welcome: Introduction by chair, Anti-trust Statement
- Update member information
- Introduction of members and visitors
- Read the 2019 October Meeting Minutes
- Discussions:
- "Recovery Area SIF (Serious Injury of Fatality) prevention" - open discussion.
- Open discussion, miscellaneous topics as requested by attendees

Participating in BLRBAC – cont'd

- Tuesday morning is the ESP Subcommittee open meeting, all submitted incidents are reviewed.
  - Attendees have printed incident summaries.
  - Basic information, boiler leak locations and some leak photos are shown on a large screen.
  - Be prepared to take notes to share when you get back to your mill.
- Tuesday, afternoon is the Operating Problem Session, submit questions ahead of time, or go to the microphone. Please share.
- Sunday and Monday nights have supplier sponsored Hospitality events, go and meet people. Tuesday is a single, jointly sponsored, Activity Night, go and meet.

Participating in BLRBAC – cont'd

- Wednesday morning is the Main Committee meeting, BLRBAC business is covered.
  - Changes to Guidelines are voted on, if ready for vote.
  - Each Subcommittee provides a report on their meeting
- Reports from AF&PA, TAPPI and Western Canada BLRBAC (if available)
- Two short technical presentations of recovery boiler topics of interest
  - Technically this is after main meeting adjournment
  - Finishes before Noon

BLRBAC ESP Subcommittee

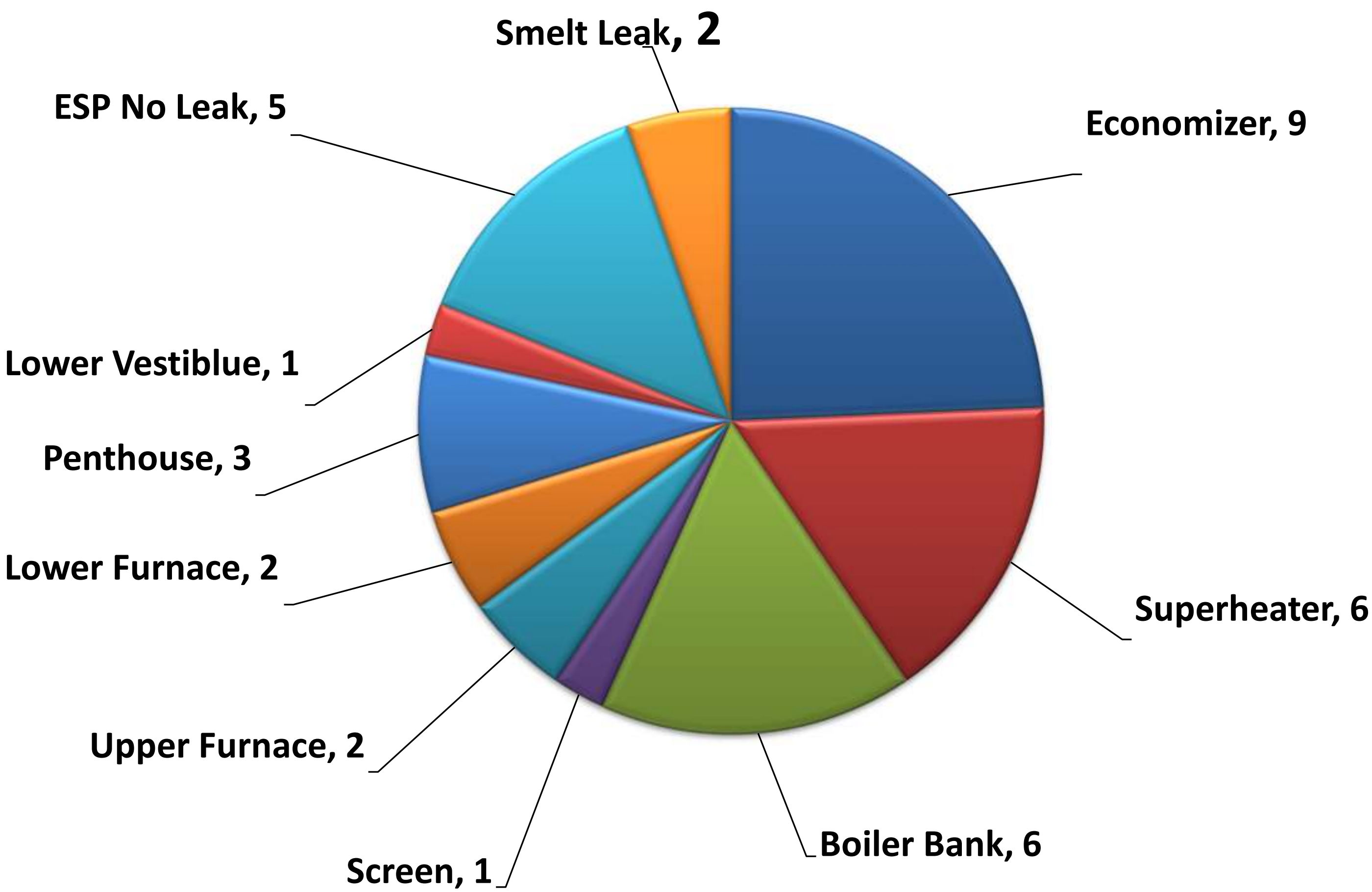
2021 Incidents ESP Report

Taken from J. Andrews BLRBAC ESP Reports for Spring and Fall 2021 reports, available in BLRBAC published Minutes

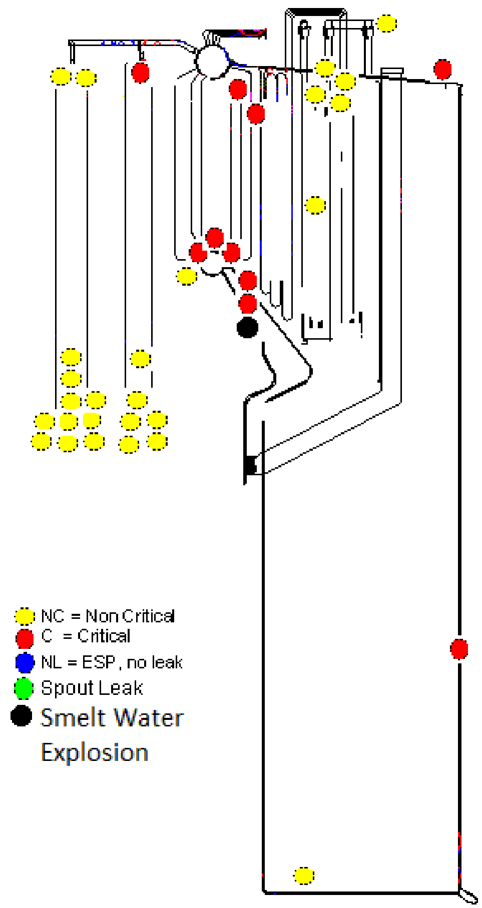
Incident Questionnaire Review

- 38 US & Canadian incidents (37 in 2020)
  - -0 Smelt Water Explosion (March 2020)
  - -0 Dissolving Tank Explosion (0)
  - -12 Critical incidents (10)
  - -18 Non-critical incidents (26)
  - - 5 ESP – No Leak (0)
  - - 2 Smelt Leak (0)
  - – 19 ESP'd (7)
    - 4 Critical
    - 89% of Critical that Should ESP (63%)
- 5 International Incidents (4 in 2020)
  - – Not included in statistical analysis

Incident Locations



Incident Locations 2020



BLRBAC Reported Leaks (US + Canada) 2004 thru 2021

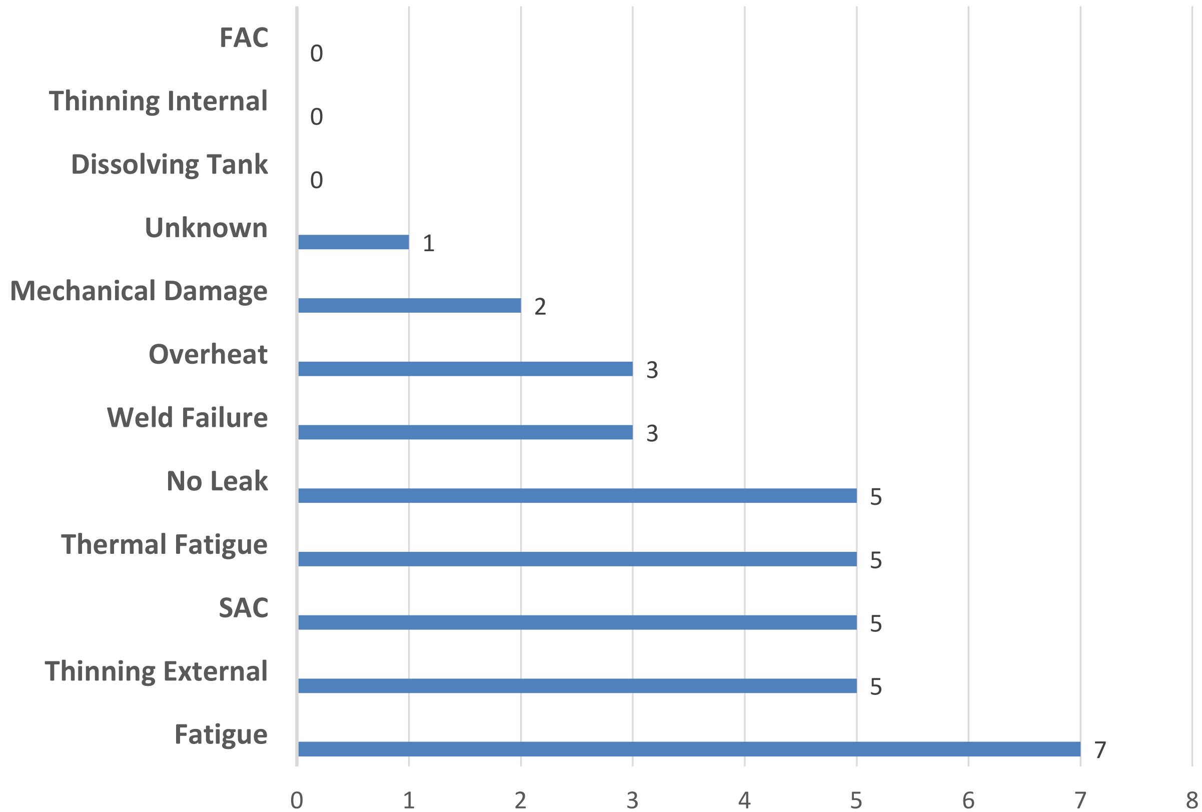
Location	18 Year Total	Average/Year
Economizer	421	23.4
Upper Furnace	128	7.1
Superheater	137	7.6
Lower Furnace*	97	5.4
Boiler Bank*	101	5.6
Screen*	40	2.2
Smelt Spout	29	1.6

*Four Smelt-Water Explosions Recorded 2004 thru 2020,
One from Boiler Bank Leak, Two Screen Tube Leaks, One Floor Leak

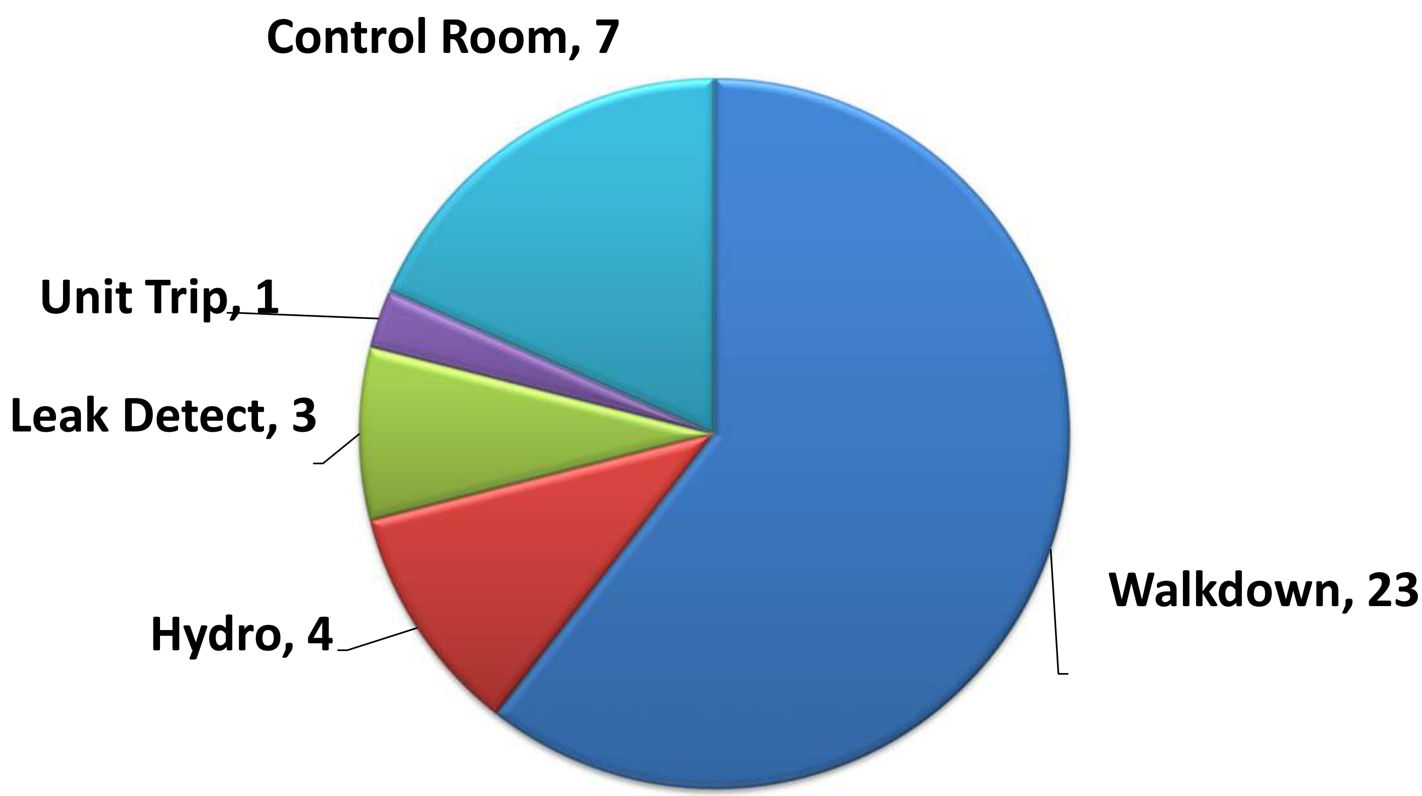
Incidents by Boiler Type

- Drums
  - 1 - 15
  - 2 - 23
  - 3 - 0
- Back End
  - Large Economizer - 32
  - Cascade - 0
  - Cyclone - 6

Leak Cause


FAC
0
Thinning Internal
0
Dissolving Tank
0
Unknown
1
Mechanical Damage
2
Overheat
3
Weld Failure
3
No Leak
5
Thermal Fatigue
5
SAC
5
Thinning External
5
Fatigue
7
0
1
2
3
4
5
6
7
8

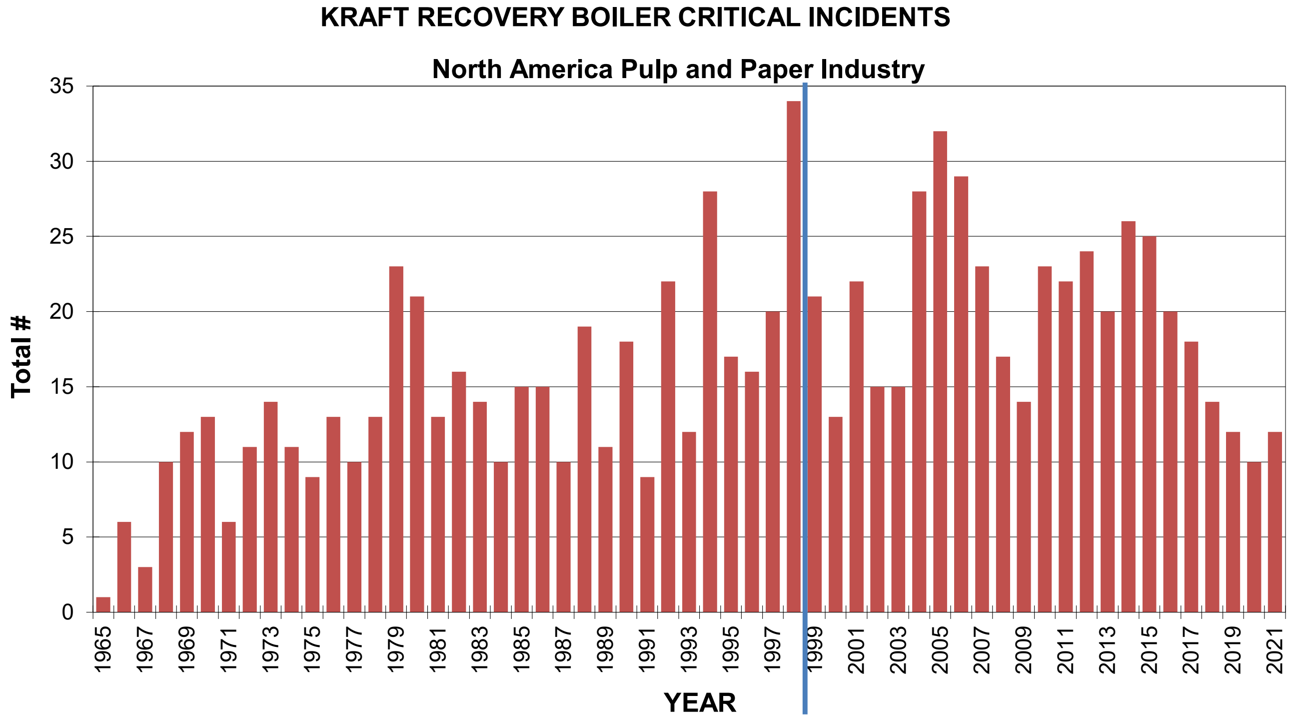
How Discovered



Leak Detection Systems

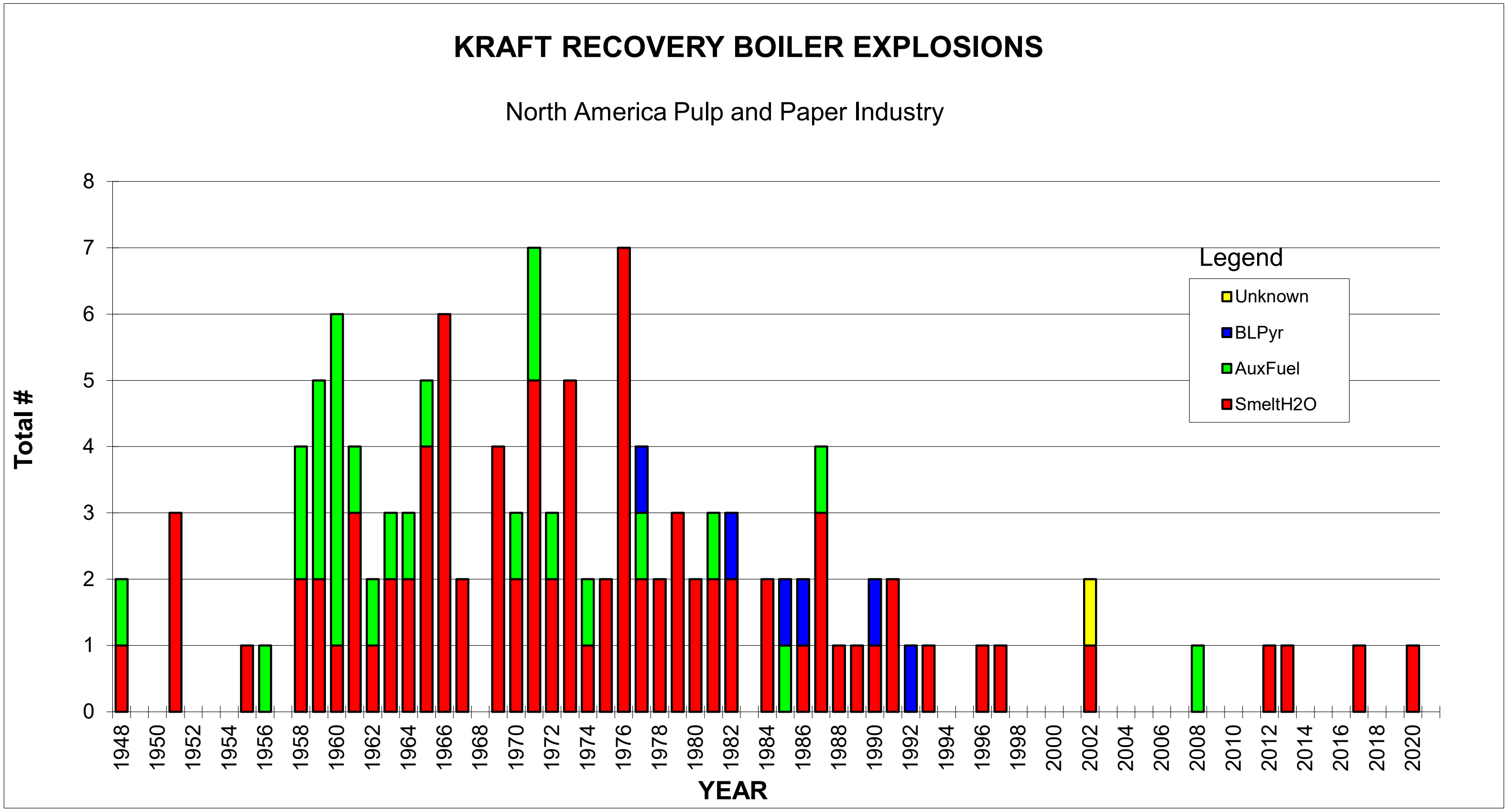
- Leak Detection Systems installed – 30
- (79%)
  - Identified leak – 3
  - Confirmed leak - 5

Critical Incidents to Date

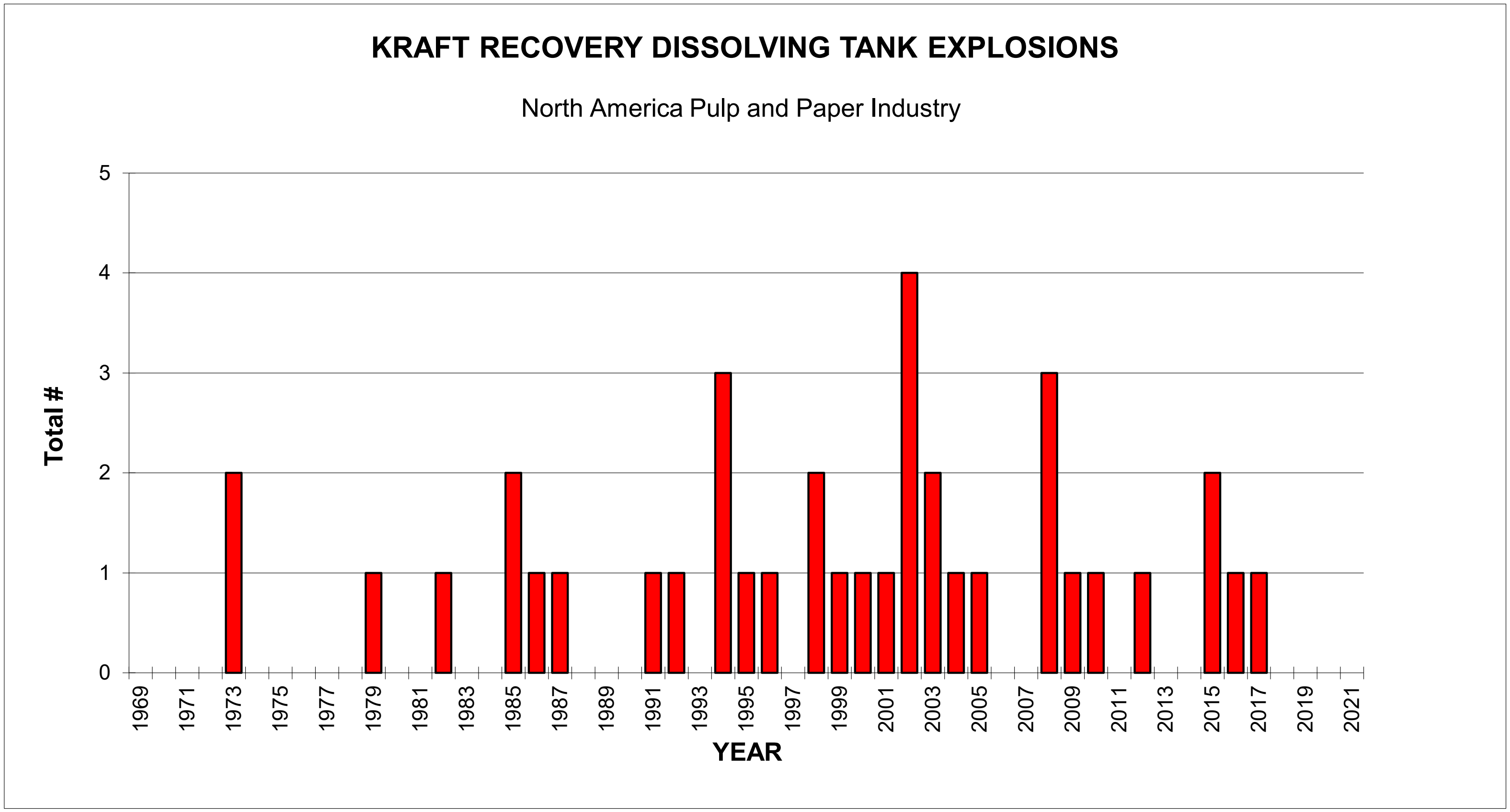


Definition change Sept 1999
Increase in critical incidents

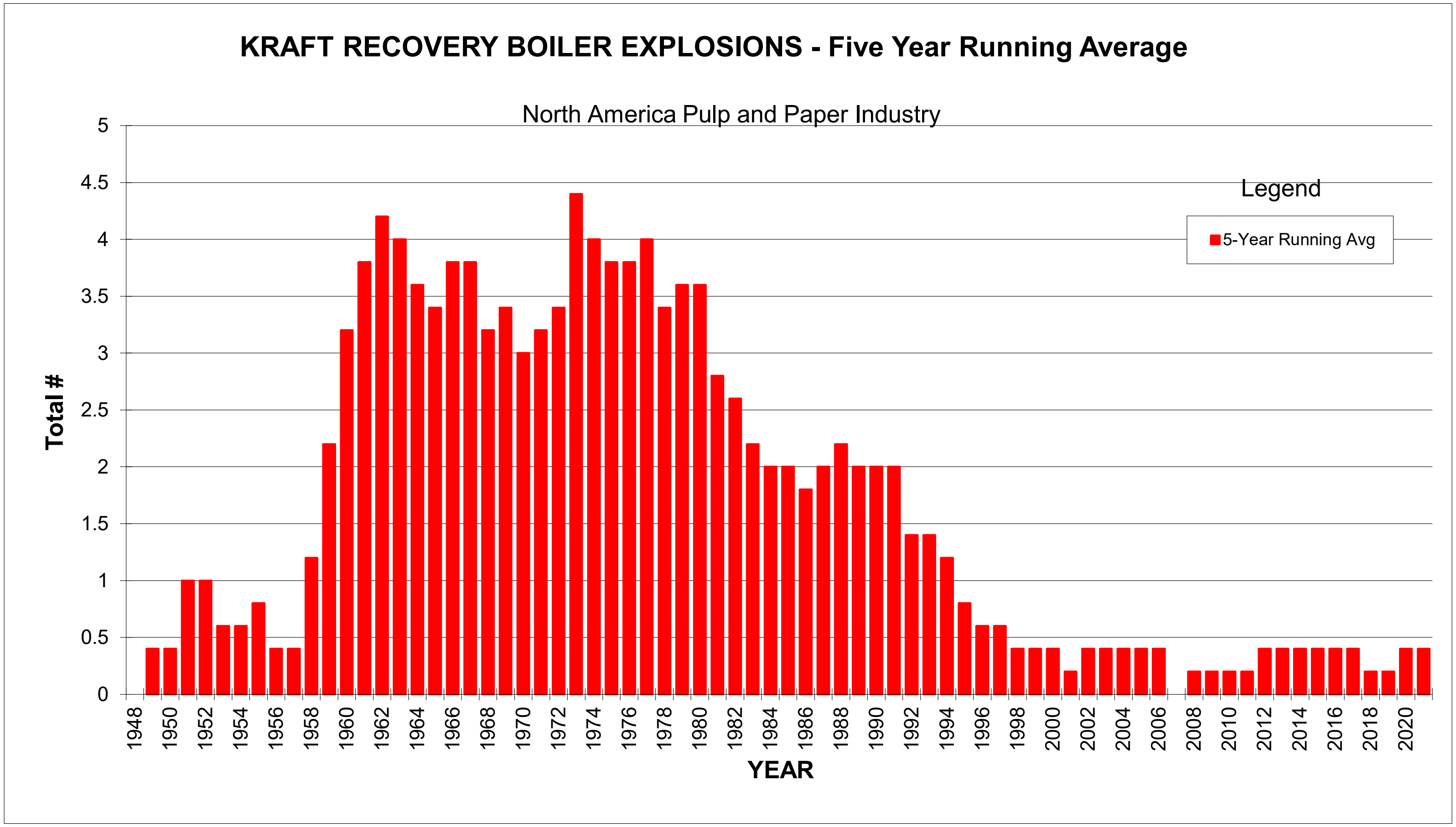
Boiler Explosion History



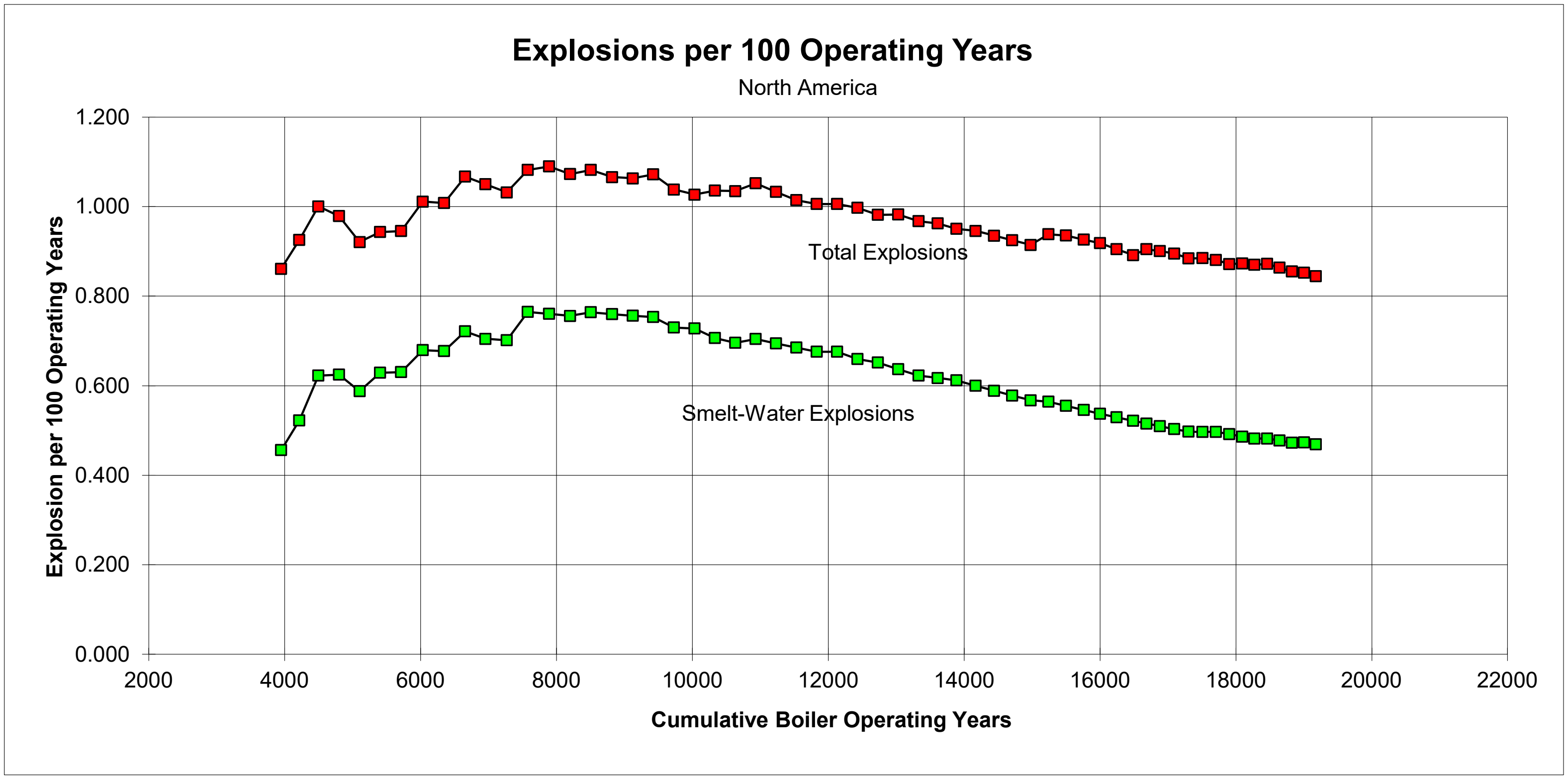
Dissolving Tank Explosions



Explosion History - Five Year Avg.



Explosion History per 100 Oper Yr



Boilers in Service

- **North American Total - 171**
-

	US	Canada
– Number	133	38
– Avg Age	41.9	44.6
– Max Age	69	74

- Oldest
  - Kruger Three Rivers, PQ
  - 1947 Alstom
- Contact Dean Clay with any Corrections or Updates

Combined ESP and Post-ESP Document

Voted and Approved by BLRBAC in Fall 2018 Meeting
Posted on Website

- Chapter 1 Purpose
- Chapter 2 Design
- Chapter 3 Post ESP Procedures
- Chapter 4 Re-Entry to Boiler after ESP
- Chapter 5 Procedure for Testing ESP
- Chapter 6 References

Incident Questionnaires

- Obtain Up to Date Questionnaire from BLRBAC at blrbac.net
- New Fill-in Form Questionnaire
- Submit to Dean Clay at dclayesp@gmail.com
  - Please use Word .doc or .docx files, not .pdf
  - Please use .jpg illustrations
- Look for confirmation of receipt from Dean

AMERICAN FOREST & PAPER ASSOCIATION RECOVERY BOILER PROGRAM STATUS UPDATE

BY

WAYNE GRILLIOT

February 1-2, 2022

AF&PA RECOVERY BOILER CONFERENCE

AF&PA Recovery Boiler Program

The **AF&PA Recovery Boiler Program**

- Established in 1974
- Identify the root cause of Recovery Boiler explosions and critical incidents
- Help improve the safety, integrity, and reliability of Recovery Boiler operations
- Membership is open to all companies & mills that operate Recovery Boilers
- Activities are funded by membership dues

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AF&PA Recovery Boiler Program

The **Recovery Boiler Program** is directed by a **Steering Committee**

- **Frank Navojosky** – International Paper
- **Wes Hill** – Georgia-Pacific
- **Jeff Wagoner** – International Paper
- **Greg Burns** – Domtar

The Recovery Boiler Program projects & initiatives are based on:

- Member Company Input
- BLRBAC Incidents
- Industry Needs

AF&PA Recovery Boiler Program

Documents developed by the Program:

- **Reference Manuals**
- **Audit Guidelines**
- **Best Practices**
- **Training Aids**
- **Checklists**
- **Textbooks**
- **Studies**

AF&PA Recovery Boiler Program

- The Program sponsors R&D projects for:
  - **Safety Improvements**
  - **Process Improvements**
- Program Projects and Initiatives focus on:
  - **Safety**
  - **Operations**
  - **Maintenance**
  - **Recovery Boiler Integrity**

AF&PA Recovery Boiler Program

Two Standing Subcommittees

- **Operation & Maintenance Subcommittee**
  - **Frank Navojosky** – International Paper (Co-Chair)
  - **Wes Hill** – Georgia-Pacific (Co-Chair)
- **Research & Development Subcommittee**
  - **Jeff Wagoner** – International Paper (Co-Chair)
  - **Greg Burns** – Domtar (Co-Chair)
- **Subcommittee Membership**
  - Representatives from the Member Companies

Membership

The AF&PA Recovery Boiler Program

- Membership is open to all mills & companies that operate Recovery Boilers
- 25 Member Companies
- 109 Mills
- 95% of the USA Capacity
- 41% of Canadian Capacity
- South American Member

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Operational Safety Seminars

- The **O&M Subcommittee** sponsors the **Recovery Boiler Operational Safety Seminars**
  - Objective: Safe Operation of Recovery Boilers
  - 2020: Three (3) Virtual Safety Seminars (Held in the Fall)
    - 122 participants representing:
    - 11 companies
    - 22 mills
- Operators, Supervisors, Superintendents, Maintenance Professionals, Engineers, and Managers attended

Operational Safety Seminars

- Attendees receive valuable information and insights from the dialogue among the attendees and monitors of the seminars
- The tabletop exercises help operators and supervisors make the important decision: **When to ESP a Recovery Boiler**
  - The six (6) Case Studies are based on actual recent BLRBAC Recovery Boiler Incidents
  - **Six (6) new Case Studies** are used for each Safety Seminar Series (Spring & Fall)
- Over **4,100** people have attended the seminars since they were started in 1985

Operational Safety Seminars

- As more senior operators and supervisors retire, **training continues to increase in importance**
- Companies are finding these seminars to be an important part of their **Safety & Training Programs**
- We continue to recommend that all companies and mills seriously consider sending people to these valuable seminars

Operational Safety Seminars

2021: Five (5) Virtual Recovery Boiler Operational Safety Seminars

- March 10, 2021 (7:45 am – 5:00 pm) Eastern Time
- April 7, 2021 (7:45 am – 5:00 pm) Pacific Time
- May 5, 2021 (7:45 am – 5:00 pm) Eastern Time
- September 22, 2021 (7:45 am – 5:00 pm) Eastern Time
- October 27, 2021 (7:45 am – 5:00 pm) Pacific Time
- Attendance has been great – **283** people attended in 2021!

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Operational Safety Seminars

2022: Four (4) Virtual Recovery Boiler Operational Safety Seminars are Planned

- April 20, 2022 - Eastern Time
- May 18, 2022 - Pacific Time
- September 2022 - Eastern Time
- October 2022 - Pacific Time
- Safety Seminar Monitors
  - **John Andrews**, BLRBAC ESP Subcommittee Chairman
  - **Dean Clay**, BLRBAC ESP Subcommittee Secretary
- More people can attend due to the lower registration fee
- **+** No travel time or cost!

Annual Conference & Meetings

2022 AF&PA Recovery Boiler Conference & Committee Meetings on February 1-2, 2022, at the Atlanta Airport Marriott

- In-Person!!!
- All relevant Covid related protocols will be followed
- Additional meeting room space has been obtained
- The Conference is open to everyone interested in Recovery Boilers
- 48 people have registered

Smelt Dissolving Tank Studies

- The **O&M and R&D Subcommittees** are both working to develop best practices around dissolving tank related issues
- The **R&D Subcommittee** is sponsoring some important research projects at the University of Toronto for improved safety and reduced operating risk of Dissolving Tanks
  - The 4 projects focus on:
    - **Dissolving Tank key operating conditions**
    - **Advanced monitoring techniques**
- The program is building on prior AF&PA studies and related research underway at the University of Toronto, funded by a consortium of 26 companies

Best Practices

- The **O&M Subcommittee** is currently working to formalize recommendations from the “Dissolving Tank Survey and BLRBAC Incidents Study” completed by Dr. Tom Grace
  - Work will continue on the project at the O&M Subcommittee Meeting today February 1, 2022
- Next **O&M Subcommittee** Project
  - **Impact of extended run time on Recovery Boilers**
    - Operations, maintenance, risk, areas of concern, and criteria for allowing extensions

Kraft Recovery Boilers “Blue Book”

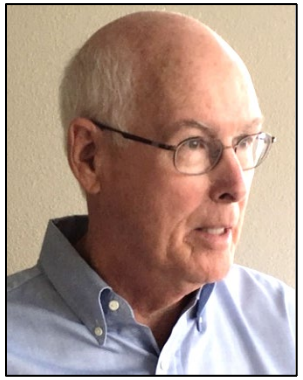
- **The AF&PA R&D Subcommittee** sponsored the publication of the new **Kraft Recovery Boilers, Third Edition** textbook
- **Dr. Honghi Tran** of the University of Toronto led the effort to author the new book – 1st available for sale in 2020
- Dr. Tran and 7 other world-renowned Recovery Boiler experts completed the 16 chapters of the new book
- Available through **TAPPI Press!!!**
- The book is also used for the **TAPPI Kraft Recovery Operations Course**
- Book sales have been very strong, with nearly **600 copies** sold
- The book will be **available for sale here tomorrow by TAPPI**

American Forest & Paper Association

Technical Editor & Chapter Author

HONGHI TRAN obtained his B.Sc. and M.Eng. from Shizuoka University in Japan, and his PhD from the University of Toronto in 1982. Honghi is Frank Dottori Professor of Pulp and Paper Engineering and Director of the Pulp & Paper Centre in the Department of Chemical Engineering and Applied Chemistry. He helped establish and direct consecutively 12 large industrial research consortia, focusing on issues related to energy and chemical recovery in kraft pulp mills. Honghi has authored or co-authored over 300 refereed papers and has 8 patents. Honghi has chaired the TAPPI Kraft Recovery Course since 2006. He was named a TAPPI fellow in 2000, PAPTAC fellow in 2015, and Canadian Academy of Engineering Fellow in 2016. Honghi received numerous prestigious awards including the 2013 PAPTAC's John S. Bates Gold Medal and the 2017 TAPPI Gunnar Nicholson Gold Medal. He was inducted to the Paper Industry International Hall of Fame in 2017.

Chapter Authors



TERRY ADAMS was an independent technical consultant to the pulp and paper industry in the area of chemical recovery until he retired in 2017. He obtained a B.Sc. from the University of California at Santa Barbara, a M.Sc. from the University of Michigan, and a Ph.D. from Drexel University with a specialty in combustion. Terry has worked as a Professor at the University of British Columbia, a Combustion Scientist at Weyerhaeuser Co., and since 1986 an independent consultant with a client base of over a hundred mills. He co-authored Kraft Recovery Boiler Physical and Chemical Processes, TAPPI Press, published in 1988 with Dr. Jim Frederick, and is the editor and co-author of Kraft Recovery Boilers, TAPPI Press, published in 1997.

Chapter Authors

MIKKO HUPA is a Chemical Engineering Professor at the Åbo Akademi University (ÅAU) in Turku, Finland. Mikko has supervised more than 40 PhD Theses and authored or co-authored more than 350 journal papers in the areas of high temperature chemistry, biomass and black liquor combustion and gasification, and fluidized bed combustion. Mikko has wide experience as an industrial consultant on issues of chemical aspects of combustion and energy processes. He has served as President of the International Flame Research Foundation, an international organization on industrial combustion with 250 member organizations in nearly twenty countries around the world. Mikko was named a TAPPI Fellow in 2005. Since 2015 he has worked as the President of his university ÅAU.

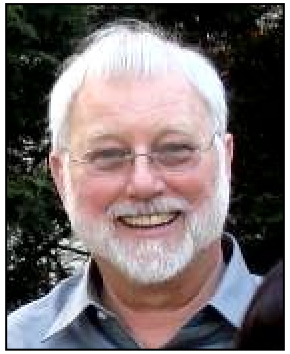
WILLIAM J. (JIM) FREDERICK, Jr. received his BS, MS, and PhD degrees in Chemical Engineering from the University of Maine. Jim has been active in kraft chemical recovery since 1975, both in industry, research, and consulting. Jim has been active with both TAPPI and the AIChE Forest Products Division throughout his career. He received the AIChE Forest Products Division’s award in 1998, and he was named a TAPPI Fellow in 2007. He co-authored the book Kraft Recovery Boiler Physical and Chemical Processes (American Paper Institute, 1988), was a contributing author to Kraft Recovery Boilers (TAPPI Press, Atlanta, 1997). He is the lead author on a new book, Black Liquor Evaporation, to be published by TAPPI in 2019.

Chapter Authors

THOMAS M. GRACE obtained a B.S. in chemical engineering at the University of Wisconsin and a Ph.D. from the University of Minnesota. He was a faculty at the Institute of Paper Chemistry (now IPST at Georgia Tech) for 22 years, and an adjunct professor at the University of Toronto for 15 years. He formed T. M. Grace Company in 1988, consulting on recovery boilers and chemical recovery. Tom has a long involvement with BLRBAC and the AF&PA Recovery Boiler Committee, investigating recovery boiler explosions for 25 years. He authored many papers and book chapters on chemical recovery. Tom was awarded the TAPPI Gunnar Nicholson Gold Medal in 2001 and inducted to the Paper Industry International Hall of Fame in 2003.

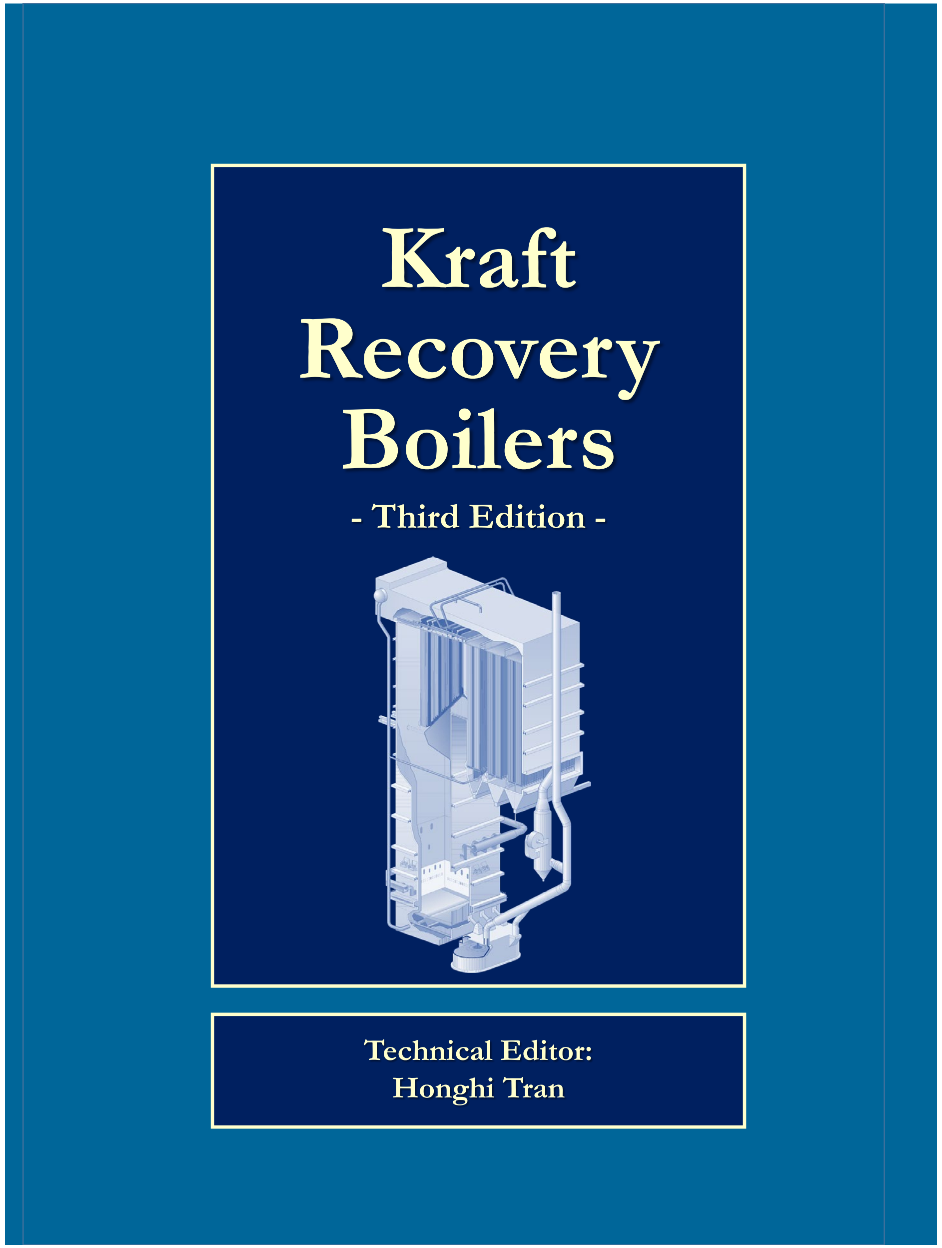
ANDREW K. JONES is a Senior Engineering Fellow at International Paper (IP) where he fosters the implementation on new process innovations. Previously he was the recovery boiler SME. He has been with IP since 1997. Previously he worked for ABB/Combustion Engineering leading an R&D group. He received his PhD from the Institute of Paper Chemistry in 1989. Andy is active in TAPPI, having led the Engineering Division, and was conference chair for the TAPPI PEERS conference. He won the TAPPI Engineering Leadership and Service Award in 2004. He was the conference chair for the ICRC (International Chemical Recovery Conference). Andy was named a TAPPI Fellow in 2016 and he received the Engineering Division Technical Award and Beloit Prize in 2018.

Chapter Authors



W.B.A. (SANDY) SHARP is a consultant specializing in solving corrosion and materials problems in pulp and paper mills and chemical plants. He has master's degrees in Metallurgy and in Corrosion from Cambridge and London Universities in the U.K. and a Ph.D. in Chemistry from the University of Ottawa. Sandy's materials engineering experience includes 28 years leading corrosion control efforts within Westvaco (now WestRock). He has published 62 technical papers in refereed journals. He developed TAPPI's short course on solving corrosion problems and has won TAPPI’s Joachim Leadership and Service Award and Engineering Division Award. Sandy is a TAPPI Fellow, a Materials Technology Institute Fellow, and the first NACE (Corrosion Engineers' Association) Fellow from the pulp and paper industry.

DOUGLAS SINGBEIL holds a BSc in Chemistry and an MSc in Metallurgy from the University of British Columbia. He began his career with FPInnovations (formerly Paprican) in 1982 as a research scientist. He has since served in numerous roles, including Corrosion Group Leader, Research Leader for Bioenergy & Corrosion, Research Manager for Process Engineering, and is currently Industrial Sector Leader for BioProducts. Over his career, Doug has addressed corrosion in recovery and biomass boilers, digesters and other process equipment. He has authored/co-authored more than 60 papers. He received awards for several of these, including the 1998 and 2004 ISCPPI Walter Mueller Awards and 2005 PAPTAC Weldon Medal. He was appointed a Fellow of NACE International in 2009.



Kraft Recovery Boilers

- Third Edition -

by

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W. James Frederick
Thomas M. Grace
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W.B.A. Sharp
Douglas Singbeil
Honghi Tran

Technical Editor
Honghi Tran

American Forest & Paper Association

TAPPI PRESS

Recovery Boiler Program Information

- AF&PA Recovery Boiler Program Website:

  http://www.afandpa.org/our-industry/recovery-boiler-program

- Recovery Boiler Program General Information

- Information on Available Documents
  - Publications
  - Studies
  - Training Aids
  - Standards

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Contact Information

- AF&PA Website:

  http://www.afandpa.org

- AF&PA Recovery Boiler Program Website:

  https://www.afandpa.org/get-involved/industry-programs#RecoveryBoiler

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Questions?

Thank You!

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